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THE SUN'S RADIANT HEAT.

By CAPTAIN JOHN ERICSSON.

From "Nature."

The readers of "Comptes Rendus" are aware that Père Secchi addressed a letter to the Academy of Sciences at Paris, some time ago (see "Comp. Rend.," tome lxxiv., pp. 26–30), containing a review of my communications to "Nature," published July 13, October 5,* and November 16, 1871,† in which he questions the correctness of the reports which I have published containing tabulated statements of the temperature produced by solar radiation. His reason for questioning the reliability of my tables appears to rest on the supposition that my instruments do not furnish correct indications. "It is astonishing," he says, "that Mr. Ericsson should find with his instrument a higher stationary temperature in winter than in summer. This (even bearing in mind the greater proximity of the sun in winter) makes me think that there must be something very singular in his apparatus, making all its indications deceptive. Even under the beautiful sky of Madrid, has M. Rico y Sinobas found, in December, for the solar radiation, 12 div., 19 by his actinometer, and, in June, 25 div., 56." It is not my purpose to prove the fallacy of M. y Sinobas' actinometric observations; but I think "that there must be something very singular in his apparatus," since in North America in lat. 40 deg. 42 min. (the latitude of Madrid is 40 deg. 24 min.), solar intensity at *noon* during the latter part of June, is 64.5 deg., when the sky is clear, while at noon during the latter part of December, the temperature under similar atmospheric conditions reaches 58.70 deg. But observations made in the morning, or evening, during the month of June, at the hour when the sun's altitude is the same as at noon in December, show that the intensity of the radiant heat in June is only 53.08 against 58.7 deg. in December. Actual observations have thus established the fact that for *corresponding zenith distance*, the temperature produced by the radiant heat when the earth has nearly reached perihelion, is 58.7 deg. — 53.08 = 5.62 deg. higher than at midsummer. Referring to the table published in "Nature," vol. 5, p. 47, it will be seen that, owing to the greater proximity of the sun, the increase of absolute intensity of solar radiation is 5.88 deg. Fahr. during the winter solstice. Père Secchi will do well to examine the subject more carefully and make himself better acquainted with the character of the investigations which have led to an exact determination of the temperature produced by solar radiation.

The readers of "Comptes Rendus," who have examined the review referred to, ignorant of the contents of the articles in "Nature," will be surprised to learn that I have not, as the reviewer asserts, questioned the

* Van Nostrand's Magazine, Vol. V., p. 599.
† Van Nostrand's Magazine, Vol. VI., p. 91.

power of vapor to diminish solar intensity. Having stated the result of numerous observations of the sun's radiant power at corresponding zenith distance, and proved that the temperature during midwinter is higher than at midsummer, I made the following remark in "Nature," Nov. 16, 1871: "In the face of such facts it is idle to contend that the temperature produced by solar radiation under corresponding zenith distance and a *clear sky*, varies from any other cause than the varying distance between the sun and the earth." It is absurd to suppose that a person having devoted many years to the investigation of solar radiation should deny the retarding influence of vapor, since not one observation in a hundred indicates maximum solar intensity, owing to the presence of vapor in the atmosphere.

The following brief description of the actinometer will show that there is not, as Père Secchi supposes, anything very singular in this apparatus tending to render its indications deceptive. The principal part of the instrument consists of an air-tight cylindrical vessel, the axis of which is directed towards the sun, the upper end being provided with a thin lens covering an aperture 3 in. in diameter. The bulb and part of the stem of a mercurial thermometer is inserted through the upper side, at right angles to the axis, a small air-pump being applied for exhausting the air from the cylindrical vessel. The latter is surrounded by a casing through which water is circulated by means of an ordinary force pump and flexible tubes, connected with a capacious cistern containing water kept at a constant temperature of 60 deg. Fahr. The bulb of the thermometer is cylindrical, 3 in. long, its contents bearing a very small proportion to its convex area. The upper half is coated with lamp-black, while the lower half of the bulb is effectually protected against loss of heat from undue radiation. The diminution of energy attending the passage of the sun's rays through the lens is made good by the concentration effected by its curvature; hence the entire energy of the radiant heat will be transmitted to the cylindrical bulb. The inclination of the latter, it should be observed, promotes a rapid upward current of the mercury on the top side, and a corresponding downward current on the lower side, thereby rendering the indication prompt and trustworthy. The water in the surrounding casing being maintained at a constant temperature of 60 deg. Fahr., it will be evident that the *zero* of the thermometric scale of the actinometer must correspond with the line which marks 60 deg. on the Fahrenheit scale. It scarcely needs explanation that the height reached by the mercurial column after turning the instrument towards the sun, will be due wholly to solar energy, since the radiation of the exhausted vessel towards the bulb of the thermometer is only capable of raising the column to the actinometric zero (60 deg. Fahr.).

The readers of "Nature" will remember that one of the articles reviewed by Père Secchi, the one published in vol. 5, pp. 449–452, contains a demonstration accompanied by several diagrams, proving that the radiant heat emitted by the chromosphere and outward strata of the solar envelope, is inappreciable at the surface of the earth. It will be remembered also that the mode adopted in settling the question whether the solar atmosphere is capable of emitting heat rays of appreciable energy, was that of shutting out the rays from the photosphere and collecting those from the chromosphere and envelope, in the focus of a parabolic reflector. Scarcely any heat being produced notwithstanding the great concentration by the reflector, we proved the fallacy of Père Secchi's remarkable assumption, that the high temperature at the surface of the photosphere is caused by *radiation* "received from all the transparent strata of the solar envelope." It is surprising that, notwithstanding the completeness and positive nature of the demonstration referred to, no allusion whatever is made to the same in a review professing to scrutinize critically the contents of the articles mentioned. Ignoring the evidence furnished by actual trial in proof of the extreme feebleness of the radiating power, the reviewer proceeds to state "that the outward strata might be less hot, and that the effect which we measure is the aggregate of the quantities of heat which are added, emanating from the various transparent strata." How the outward colder strata cause an elevation of temperature by their radiation towards the solar surface, is not explained, but reference is made to the result of an experiment with three small flames, in support of the assertion that the high temperature of 10,000,000 deg. C., assigned to the surface of the sun, is owing to radiation received from all the transparent

strata surrounding the photosphere. The reviewer states: "A very simple experiment made at my request by P. Provenzali, has shown that, if a heating of 2.5 deg. can be obtained with one flame, with two flames placed one before the other, 4.5 deg. are obtained, with three flames, 5.4 deg.—a result easily foreseen, for everybody knows that flames are transparent."

My practical demonstration establishing the feebleness of the radiating power of the matter composing the solar envelope, having received no consideration, while the reviewer, in support of his singular theory of solar temperature, points to the result of the rude experiment conducted by Père Provenzali, I have deemed it necessary to show that the transparency of flames is too imperfect to warrant the inferences drawn.

The accompanying illustration (see frontispiece) represents an apparatus by means of which the exact degree of transparency of a series of flames has been ascertained.

Description: *b*, conical vessel, open at the top, the bottom communicating with a cylindrical chamber *f*, by an intervening narrow passage, the whole being enclosed in an exterior vessel *c*, charged with water kept at a constant temperature, precisely as in the actinometer. A thermometer is applied near the bottom of the cylindrical chamber, the centre of the bulb coinciding with the prolongation of the axis of the conical vessel. A gas pipe *d*, provided with a series of vertical burners, is firmly secured to a table in a position parallel to the axis of the conical vessel. The burners are provided with caps in order to admit of any desirable number of jets being ignited at one time. When gas of ordinary pressure is admitted into the pipe *d*, the side view of the flame will be as indicated by the dotted lines at *m m*, the thickness of each flame being nearly 0.20 in., while the width shown by the dotted lines *n n*, somewhat exceeds 3 in. from point to point. It will be observed that the prolongation of the axis of the conical vessel upwards, passes through the central portion of the flames at the point of maximum thickness and intensity. Supposing that the instrument (attached to a table turning on declination axis within a revolving observatory) is directed towards the sun, it will be evident that all the rays of a beam the section of which corresponds with that of the bulb of the thermometer, will pass through the flames before reaching the said bulb. Now the temperature of the flames at the point pierced by the solar rays is fully 2,000 deg. Fahr., while the intensity of the rays does not exceed 60 deg. The illustrated device enables us to ascertain whether the rays thus entering at a temperature 1,940 deg. lower than that of the incandescent gas, have their intensity augmented or diminished during the passage through the heated medium. But before we can determine this question, it will be necessary to ascertain what temperature is communicated to the thermometer by the radiant energy of the flames. Accordingly, a series of experiments have been made, the result of which is recorded in the annexed table.

The Instrument turned away from the sun.			The Instrument directed towards the sun.		
Number of flames from the top.	Distance of flame from bulb.	Temperature produced by radiation of the flames.	The sun's rays acting directly on the bulb.	The sun's rays passing through the flames.	Increment of temperature attending the passage of the solar rays through the flames.
	Inches.	Deg. Fah.	Deg. Fah.	Deg. Fah.	Deg. Fah.
1	24 8	1 76	21 60	21.90	0 30
2	23.8	2.88	21.61	22.20	0 59
3	22 8	3 80	21.62	22 49	0.87
4	21 8	4.58	21 63	22.75	1.12
5	20.8	5.24	21 64	22.99	1.35
6	19.8	5.84	21.65	23.32	1.57
7	18 8	6.38	21 66	23 43	1 77
8	17 8	6 91	21.67	25.63	1.96
9	16 8	7.40	21.68	23 82	2 14
10	15 8	7.90	21 69	24 00	2.31

The nature of the investigation will be readily understood from the following explanation: The instrument being turned away from the sun and the upper flame *m* ignited, while the external casing *c* is kept at a constant temperature of 60 deg., the column of the thermometer at *f* slowly rises to 61.76 deg. The radiant heat, therefore, of a single flame, produces a differential temperature of 61.76—60=1.76 deg. The second flame being ignited, the temperature rises to 62.88 deg., thus increasing the differential temperature to 2.88 deg. The ignition of the third flame augments the differential temperature to 3.80 deg. The remaining flames being ignited in regular order downwards, their combined radiant energy elevates the temperature to 67.90 deg. Deducting the temperature of the enclosure *c* (60 deg.), the trial shows that, although the single flame at the maximum distance from the bulb is capable of producing a differential temperature of 1.76 deg., the energy of the *ten* flames together produces only 7.90 deg. This fact furnishes conclusive evidence of the imperfect transparency of the flames. Assuming that the heat rays are capable of passing freely through the incandescent medium, it will be perceived that the entire series of flames should produce a differential temperature of $1.76 \times 10 = 17.6$ deg., showing a retardation of $17.6 - 7.9 = 9.7$ deg. And if we take into account the diminished distance of the lower flames from the bulb of the thermometer, it will be found that the actual retardation greatly exceeds this computation. We have thus demonstrated that flames are not transparent, as supposed by Père Secchi; consequently, the inferences drawn from the experiment to which the distinguished *savant* refers in his letter to the French Academy of Sciences are wholly unwarrantable.

Having disposed of the question of transparency and ascertained the degree of temperature communicated to the thermometer by the radiant energy of the flames alone, let us now suppose that the instrument has been turned towards the sun. The temperature produced by the combined energy of solar radiation and the radiation of the flames, after directing the instrument towards the luminary, will be found recorded in the fifth column of the table. Our space not admitting of a detailed statement, we must dispense with an examination of the energy transmitted for each flame separately, and at once consider the effect produced by passing the sun's rays through the entire series. It has already been stated that the radiation of all the flames combined imparts a differential temperature of 7.90 deg. to the thermometer. By reference to the table it will be seen that the temperature produced by the sun's rays is 21.69 deg. when the flames are extinguished.* Consequently the temperature, after lighting the whole series, ought to be $21.69 + 7.90 = 29.59$ deg., since solar heat, under analogous conditions, is capable of increasing, definitely, the temperature of substances, whatever be their previous intensity.† Referring again to the table, it will be found that the maximum increase of temperature attending the passage of the comparatively cold solar rays through the incandescent gas is 2.31 deg., while the radiant energy of the flames produces a differential temperature of 7.90 deg. This extraordinary discrepancy points to an increase of molecular energy within the incandescent gas, notwithstanding its temperature being fully 1,900 deg. higher than that produced by the sun's radiant heat.

* Notwithstanding the low temperature indicated by the thermometer of the experimental apparatus, 21.69 deg. the actual solar intensity during the investigation, ascertained by the actinometer, has at no time been less than 50 deg.—a very instructive fact, proving the futility of attempting to measure solar intensity by thermometers the bulbs of which are exposed to the refrigerative action of surrounding air. For the purpose in view, however, that of measuring the comparative radiant power of flames and solar heat, the unavoidable exposure of the bulb to atmospheric influence is unimportant, provided the enclosure be kept at a constant temperature during the experiments.

† Père Secchi reminds us in "Le Soleil," that Mr. Waterston found by his solar intensity apparatus that, when the thermometer was enclosed in a heated vessel imparting upwards of 400 deg. Fahr. to the bulb, the same degree of differential temperature was reached by exposure to the sun as when a cold enclosure was employed, which reduced the indication of the enclosed thermometer to that of ordinary atmospheric temperature.

Edwin F. Johnson, one of the most eminent of American Engineers, died on the 12th inst., and was buried at his home in Middletown, Conn. He was Engineer in Chief of the Northern Pacific Railroad until a little more than a year ago, and since has been Consulting Engineer of that Company.

Not long ago, the whole stock of the paraffine wax in the world did not exceed 4 ounces, which was carefully preserved in the laboratory of Prof. Liebig as a chemical curiosity. There is now produced in Scotland not less than 5,800 tons annually.

UNIFORM CROSS SECTION AND T ABUTMENTS; THEIR PROPER PROPORTIONS AND SIZES, DEDUCED FROM RANKINE'S GENERAL FORMULA OF EARTH PRESSURE.

By WM. CAIN, C. E.

Written for Van Nostrand's Magazine.

NOTE.—To the practical man, who is not familiar with Rankine's method, I will say, that, as the general formula of Rankine gives, for rectangular walls, what he knows to be working values, *when the earth is level at top*, and there is a line of demostration carried out for approximations over values based upon this simple case, it is hoped that so much of the following, at least, will be useful and intelligible to him. The strict formulæ are likewise deduced.

1. This investigation is for the purpose of pointing out, by several practical solutions, the principles that are to guide an engineer in designing his abutments, whether of uniform section or the common T form, *so far* as the pressure of the earth against them is to be the criterion in proportioning and sizing them.

Abutments with wing walls are mentioned only by way of comparison.

2. The first thing that is necessary to know is the specific gravity of the earth, whose weight causes the pressure, conjointly with the specific gravity of the masonry, whose weight resists this pressure.

The following table, from various good authorities, on account of the variations in the numbers, should teach caution in assuming too favorable values, as we may remark here, that the pressure and resistance are, both, *directly* as the specific gravities of the earth and masonry respectively.

	Weight per cubic foot in lbs.	Angle of repose. ○
Water	62.4	0
Mud	102.	0–(?)
Shingle and gravel.	90–109. –120	35–48
Clay	120.	14–45
Gravel and earth	126.	
Settled earth	120–137	21–37
Dry sand	89	34
Damp sand	128	
Masonry	110–144	
Brickwork	110	
Brick	90–135	
Mortar	86–109	
Granite	164–172	
Sandstone	130–157	

The engineer should get the specific gravities of his materials by actual weighing. Knowing the specific gravity of the stone used and that of the mortar, as also their relative proportions, the specific gravity of the masonry follows. For dry masonry, it will depend upon the proportionate volume of spaces to solid material. If small chips and spalls are well packed in, this proportion will be nearer that of a solid wall than of a loose rock embankment where it is said to be one-half.

Taking the minimum values above, we may assume as safe values generally:

Brickwork, weight of a cu. ft = 110 lbs.
Granite, ½ ashlar and ½ rubble backing, weight of a cu. ft. = 142 lbs.
Sandstone, ½ ashlar and ½ rubble, weight of a cu. ft. = 113 lbs.

Sandstone, though, is very variable, and it is usually heavier than this, average probably 128 lbs.

3. The *general formula of Prof. Rankine*, resulting from his elegant theory of internal stress and frictional stability, to *prevent overturning of a wall, of uniform cross section about its edge where the base* of the wall is horizontal, is:*

$$W(q+q^1)\,t = \frac{w_1 h^3 \cos\theta}{6} - \frac{w_1 h^2 t (q + h) \sin\phi}{2} \qquad (1)$$

W = weight of wall per unit of length (foot)
= volume × w, calling w = its specific gravity,
t = diameter of base perpendicular to length,
qt = Distance of centre of base from centre of pressure = safe lever arm of masonry, when $q^1 t = o$. and generally taken = $\frac{2}{3} t$ (*as* there is crushing of the outside blocks when the wall overturns, the usual $\frac{1}{2} t$ is too much).
$q^1 t$ = Distance from centre of base to the point where the vertical from the centre of gravity of the wall cuts the base.

The first side of the equation is evidently the weight of masonry × its safe lever arm, called its moment of stability.

For horizontal topped bank of earth

$$W_1 = w^1 \frac{(1 - \sin\phi)}{(1 + \sin\phi)}.$$

For top of earth sloping at angle of repose ϕ

* Rankine's Applied Mechanics, 4th London Ed., p. 251.

$W_1 = w^1 \cos \phi$
ϕ = Angle of repose of the earth from a horizontal line
θ = Slope of bank on top with horizon, which we shall take either = 0 or = ϕ, hereafter.
h = height from base to where the top of earth strikes the wall.

The second side of this equation is the moment of pressure of the earth per unit of length (foot).

Calling P, the thrust of earth, h high on wall, per unit of length, then:*

For *level topped bank*

$$P = \frac{w^1 (1 - \sin \phi) h^2}{2 (1 + \sin \phi)}$$

" top slope of bank = ϕ

$$P = \frac{w^1 \cos \phi h^2}{2}.$$

4. *Rectangular Walls.* Case 1. Horizontal topped bank on level with top of wall.

Here $\theta = 0$, $q^1 = 0$ and eq. (1) becomes

$$w t h q t = \frac{w^1 (1 - \sin \phi) h^3}{6 (1 + \sin \phi)} \qquad (2)$$

$$\frac{t}{h} = \sqrt{\frac{w^1 (1 - \sin \phi)}{6qw (1 + \sin \phi)}}$$

For $w^1 = 130$, $q = \frac{3}{8}$, $\phi = 34°$

$$t = h\sqrt{\frac{16 \cdot 2}{w}} = \frac{4h}{\sqrt{w}} \text{ nearly}$$

when		
	$w = 110$	$t = .38\ h$
	$= 128$	$t = .35\ h$
	$= 142$	$t = .34\ h$

values which are well known to be safe.

For $w^1 = 120$, $\phi = 45°$

$$t = \frac{3h}{\sqrt{w}}$$

when		
	$w = 110$	$t = .29\ h$
	$= 130$	$t = .26\ h$

It is evident once for all from table 2 and eqs. (1) and (2) that shingle and gravel form the best material for putting next abutments or retaining walls, as their angle of repose is the largest; neither is it variable, water draining through it rapidly and never making *mud*, with almost a fluid pressure. Their specific gravity is as small as any, likewise. Next follows pure sand; but a certain proportion of sand and clay, called quicksand, is worst of all, as it is similar to water pressure, with a specific gravity greater than water. Many old walls show a bulge at $\frac{1}{3}$ the height, from not leaving holes in them to drain off the water. With abutments there is no necessity for these openings, unless with wing wall abutments, as the water can generally drain off at once.

5. Case 2. *Height of level topped bank* (= h) *above base, is not so great as height of wall* (= H) *above base.* By eq. (1) when $W = w^1$, $\theta = 0$, $q^1 = 0$, $\phi = 34°$, $q = \frac{3}{8}$

$$t = \sqrt{.125 \frac{h^3}{H}}$$

For		
	$h = \frac{1}{16}$ H,	$t = .32$ H
	$= \frac{1}{8}$ H,	$t = .29$ H
	$= \frac{5}{16}$ H,	$t = .27$ H
For	$h = \frac{3}{4}$ H,	$t = .23$ H
	$= \frac{2}{3}$ H,	$t = .19$ H
	$= \frac{1}{2}$ H,	$t = .13$ H

6. Case 3. *Top of earth sloping at angle of repose.*

Put $q = \frac{3}{8}$ $\theta = \phi$ $q^1 = 0$ then by eq. (1)

$$w t H q t = \frac{w^1 \cos \phi h^3}{6} - \frac{w^1 \cos \phi \sin \phi h^2 (q + 3) t}{2} \qquad (3)$$

For $w = w^1$ $\phi = 34°$

$$t = -\frac{h^2}{4H}\sqrt{\left\{\left(\frac{h^2}{4H}\right)^2 + \frac{.304h^3}{H}\right\}}$$

When		
	$h = \frac{7}{8}$ H	$t = .3$ H
	$h = \frac{2}{3}$ H	$t = .2$ H
	$h = \frac{1}{2}$ H	$t = .14$ H

values practically the same as those in Case 2, §*5 for the same rules of h.

The use of this analogy is evident; as the simplest formulæ of §5 may be used, where sloping topped earth strikes an abt.

7. *When the wall is equally battered on both sides*—$q^1 = 0$, etc. The formula is easily obtained from eq. (1).

8. *One side vertical, the other battered.*

Let t = thickness or diameter at bottom
t_1 = " " " " top.

Then by mechanics

$$q^1 t = \tfrac{1}{2}t - \frac{t^2 + tt_1 + t_1^2}{3 (t + t_1)} = \frac{t^2 + tt_1 - 2t_1^2}{6 (t + t_1)}$$

Let $\theta = 0$ $q = \frac{3}{8}$, then by eq. (1), (see Fig. 1),

$$\frac{t + t_1}{2}\left(\tfrac{3}{8}t + \frac{t^2 + tt^1 - 2t_1^2}{6 (t + t_1)}\right) = \frac{w^1 (1 - \sin \phi)}{6w (1 + \sin \phi)} h^2$$

calling b = batter = $\frac{\text{Distance out in } 1'}{1'}$

then $t = t_1 + bh$.

* Rankine's A. M., p. 251.

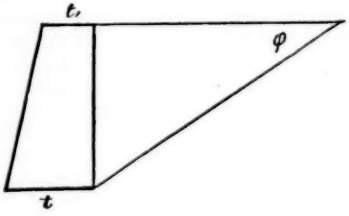
* This symbol signifies "article."

Reducing and substituting we get

$$18t_1^2 + 39t_1bh + 13b^2h^2 = 48\,\frac{w^1\,(1-\sin\phi)}{6w\,(1+\sin\phi)}\,h^2$$

$$\sqrt{\left\{\frac{8w^1\,(1-\sin\phi)}{3\times 6\,(1+\sin\phi)} + 45b^2\right\}} - 1.083b$$

Fig. 1.



Examples.

Let $q = \frac{3}{8}$ $w^1 = 130$ $b = \frac{1}{12}$ and $\phi = 34°$

$$t_1 = h\left(\sqrt{\frac{16.2}{w}} - .09\right)$$

For	$w = 110$	$t_1 = .29\ h$
	$w = 128$	$t_1 = .26\ h$
	$w = 142$	$t_1 = .25\ h$

An abutment of this kind has been used with a front batter of 3″ to 1′ = $\frac{1}{4}$; from (4) we find for $b = \frac{1}{4}$ $W^1 = 130$ $q = \frac{3}{8}$ $\phi = 34°$.

When	$w = 110$	$t_1 = .15\ h$
	$w = 128$	$t_1 = .12\ h$
	$w = 142$	$t_1 = .11\ h$

The earth which would otherwise fall in front of the abutment should be *built up* and riprapped at 45° or less. A side batter may be used or not.

Any abutment can have a side batter of 1½ to 1, with the earth; t_1 varies regularly with the height and is found by eq. (4) for a battered wall or by eq. (2) for a rectangular wall. Consequently first find 6 for maximum and minimum h and draw straight lines to limit the other values.

9. A train or wagon, passing over a bank retained by an abutment, increases the thrust of the earth, thereby necessitating an increase of size on this account alone. The formula is easily found. Take the case of a train of cars, the greatest pressure of which is usually taken=1 ton per foot longitudinally. If 12 is the width of roadway at top, then p_o = intensity of pressure of train per sq. ft.=$\frac{2240}{12}$=190 lbs. in round numbers.

For a rectangular wall 12 ft. wide, the eq. of equilibrium is:*

$$q'wht^2 = \left(p_o + \frac{w^1h}{2}\right)h\,\frac{(1-\sin\phi)}{(1+\sin\phi)} \times \frac{b_1 + 2b^2}{b_1 + b^2}\,\frac{h}{3} \qquad (5)$$

where

$$b_1 = \frac{(1-\sin\phi)\,(p_o + w^1h)}{(1+\sin\phi)\qquad w^1} \;\&\; b_2 = \frac{(1-\sin\phi)\,p_o}{(1+\sin\phi)\,w^1}$$

This multiplier

$$\frac{b^1 + 2b_2}{b^1 + b^2}\,\frac{h}{3}$$

is the lever arm of the force and varies between $\frac{1}{2}h$ and $\frac{1}{3}h$, the former when $h = o$, the latter strictly when $h = \infty$ though practically for *hts* of 20′ to 30′, when the weight of the train becomes small compared with the weight of the prism of earth that causes the pressure.

For $\phi = 34$ and $p_o = 190$ lbs. (hence w and w^1 must $= w^1h$ per *cub. ft.* in *lbs.*

$$\tfrac{3}{8}\,wt^2 = \left(190\text{ lbs.} + \frac{w^1h}{2}\right).28 \times \left(\frac{(.28w^1h + 159)\,h}{(.28w^1h + 106)\,3}\right)$$

compare eq. (2). For $h = 1$ this multiplier or lever arm $= \frac{5}{12}h$.

Example 1.

Let $w = w^1$ $h = 4$ then $t = 2.1 = \frac{1}{2}h$ nearly.
by eq. 2 $t = .35h$.

Cattle guards and open drains should then, for heights of 2, 3, 4, 5, etc., ft., have the part 12 ft. long designed by this formula (5); the wings as before.

A usual proportion for these widths is half the height. The weight of the engine is in part felt by it from the connection of the stringers and rails before it reaches the abutment, making the left side of eq. (5) larger; but its momentum may counteract this; so it is better to build by that eq.

Example 2.

Let $w = w^1$ $h = 20$ then $t = 7.7 = .39h$
by eq. 2 $t = .35h$.

It can be seen from these illustrations how much an abutment, battered or not, should be increased in thickness from the weight of a train passing.

10.—Sliding along the Base.—Let the pressure of earth, which = P and is paral-

* Found by putting $p_4 = (p_o + w_4)\cos\theta$. in eq. 1, Arts 195. et seq. of Rankine's Applied Mechanics, and deducing eqs. (2) and (3) of Art. 198, by making $s = 0$ we get eq. (5) above = their product.

lel to top slope of bank, be resolved into two components, P sin θ and P cos θ, the first vertical, the last horizontal, then if f = coefficient of friction of foundation,

$$(W + P \sin \theta) f \text{ must be} > P \cos \theta$$

to prevent sliding (see § 3 for values of P),

$$\therefore f \text{ must be} > \frac{P \cos \theta}{W + P \sin \theta} \quad (6)$$

When $\theta = 0$

$$f \text{ must be} > \frac{P}{W} \quad (6^*)$$

The rectangular wall is usually safe from sliding. Let us try the battered wall with horizontal topped bank.

$$f \text{ must be} > \frac{P}{W} = \frac{W^1 (1 \sin \phi) h}{W (1 \sin \phi) (t + t_1)} \quad (7)$$

When $w = w^1$, $\phi = 34°$; $t_1 = .26h$ for $b = \frac{1}{12}$, then

$$f \text{ must be} > .5 = \tan 27°.$$

For a good clay or rock foundation f is usually taken $= \frac{2}{3}$; the "usual tables" give for

Masonry on wet clay.....	f	$= .33$
" " timber.....		$= .4$
" " dry clay		$= .5$
" " rock.....		$= .6$ to $.7$.

The imbedding the stones in the earth, giving an irregular uneven surface of contact for the foundation, necessarily increases the friction over the figures in the above table; otherwise, when f is less than .4, about, eq. (1) is no longer needed, but we must design our abutments from eq. (5), to resist sliding, alone.

For instance for a rectangular wall

$$f \text{ must be} > \frac{3}{4} \sqrt{\left(\frac{W^1 (1 - \sin \phi)}{W (1 + \sin \phi)}\right)} \quad (8)$$

For $w = w^1$ and $\phi = 34°$ f must be greater than .4. If any f is assumed then by eq. (5) t can be found to resist sliding.

As, in battered walls the proportionate $\frac{P}{W}$ to rectangular walls is increased, there is more danger from sliding. For the abutment where $b = \frac{1}{4}$ § 8, let $w = w^1$ $\phi = 34$, then by eq. (7)

$$f \text{ must be} > \frac{.28}{2t_1 + bh} = .6 = \tan 31°,$$

which requires a good rock bottom, and there is not so much economy as with a less batter unless the foundation f is $> \frac{2}{3}$. Even for an increase in the weight of $\frac{1}{2}$, f must be $> .4$, or the same as for a rectangular of same weight.

Of course, in practice, larger values than these strictly equilibrated ones, should be used, for both sliding and overturning; as a long wet spell may make the foundation slippery and the earth pressure much greater.

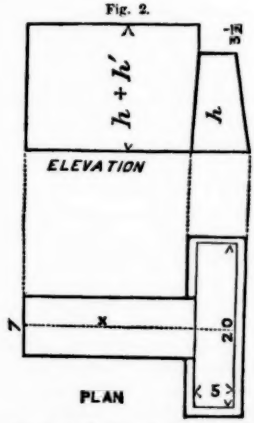
The increasing the size is otherwise beneficial in this, that in place of the *resultant* of earth pressure and weight of masonry, striking the base $\frac{3}{5}$ t from its centre, it throws this centre of pressure nearer the middle of the base, thus equalizing the thrust more on the whole foundation.

Experience has determined and theory confirms, that a batter of $\frac{1}{12}$ or $\frac{1}{24}$ is best; as the proportion of $\frac{t}{h}$ is about the same to resist overturning or sliding on ordinary foundations where $f > .5$ or .45. A vertical wall would be necessary for a timber foundation where $f = .4$. Accurate practical information on this subject is much needed.

12. T ABUTMENTS.—Let us suppose first on the side of extreme caution, that the earth is level at the height $h + h^1$ (see Fig. 2) or at the top of the *stem up* to the *head* of the abutment.

The T abutment (Fig. 2) is composed of the *head* 5×20 ft. on top and battered 1.12 ft. all around, and the *stem* perpendicular to its length, vertical on the sides and at one end, and 7 in. across.

Fig. 2.



The height of the head $= h$. The height of the head and stem $= h + h^1$; h^1 here $= 3.5$ ft. Call b as before = batter; call ψ = distance from front face of top of head to end of stem.

Now the earth presses against $(13 + bh)^1$

in length of head for the height $h_1 \times h$ (this is very nearly correct for this steep batter) and against 7′ of stem at end.

According to the well-known theory of statical moments the sum of the moments of the forces caused by the pressure of earth = (weight of part of head on both sides of stem) × its lever arm + (weight of stem and rest of head) × its lever arm. The moment of stability (see § 3) of part of head on both sides of stem $= (5 + bh)\ (13 + bh)\ h\ (5 + 2bh)\ \frac{3}{28}w$. Do. rest of head and stem $= 7h^1\ (\psi - 5)\ \frac{3}{8}\ (\psi + bh) + 7h\ (\psi + \frac{1}{2}bh)\ \frac{3}{8}\ (\psi + bh)$. The usual apparent computation of volumes being used.

The moment of earth pressure is (eq. 2)

$$= (20 + bh)\ \frac{w^1\ (1 - \sin\phi)^1\ (h + h^1)^3}{6w\ (1 + \sin\phi)},$$

Putting $\phi = 34°$ we have, when there is equilibrium, from overturning,

$$(5 + bh)\ (13 + bh)\ h\ (5 + 2bh)\ \tfrac{3}{28} + [7h'\ (\psi - 5) + 7h\ (\psi + \tfrac{1}{2}bh)]\ (\psi + bh)\ \tfrac{3}{8} = (20 + bh)\ \frac{.047\ (h + h')^3 w'}{w}. \qquad (9)$$

For $h = 24$ $w = w^1$, the stem projects but 2 or 3 ft.
" $h = 36$ and $w = w^1\psi = 19^1.3$, or clear stem of 14.3 feet.
For $h = 60$ and $w = w^1\psi = 39^1.2$, or clear stem of 29.2 feet.

These are large values, as will be shown § 13, though often longer stems are built; even $1\frac{1}{2}$ times the height is used, though here the object is to prevent the earth running in front of the abutment so that no washing away of it will occur. By diminishing the water-way some, the T abutment can be built just large enough to resist earth pressure; then the bank can be protected from washing by a foot wall and riprapping at a steep slope. Wing wall abutments will on this account give more water-way or less bridge, though costing more than the T abutments. A calculation in each case of which is cheapest in the end must be made, as the life of bridge trusses vary, and the amount of riprapping is dependent on high-water mark and velocity of the stream.

The mere saving in bank from a long stem is nothing like the extra cost of masonry. The difference minus the cost of riprapping so as to give the same water-way with a shorter stem, being so much money wasted.

13. The true solution for this and all similarly shaped abutments (calling h_o = height at which earth strikes head and t = diameter of base of head) is this. The first side of eq. (9) (as the earth slopes against head abutment $\theta°$ deg) must by eqs. (3) and (2)

$$(13 + bh)\left[\frac{w^1 \cos^2\phi h_o^3}{w \times 6} - \frac{w^1 \cos\phi \sin\phi h_o^2 t(q + \frac{1}{2})}{2}\right] + 7\,\frac{W^1\ (-\sin\phi)\ (h + h^1)^3}{6W\ (1 + \sin\phi)},$$

when $\phi = 34°$ $9 = \frac{3}{8}$, we deduce (10)

$$(5 + bh)\ (13 + bh)\ h\ (5 + 2^1 h)\ \tfrac{3}{28} + [7h'\ (\psi - 5)\psi + 7h\ (\psi + \tfrac{1}{2}bh)]\ \tfrac{3}{8}\ (\psi + bh) = \frac{W'}{W}[(13 + bh)(.114h_o^3 - .2bh_o^2) + 7 \times .47(h + h')^3$$

This *form* will answer for different dimensions, see § 23. There would not be much error in considering earth level on head at height h and on stem at $h + h^1$, see §§ 6 and 7. It is evident that the length of stem, as the earth slopes from it, determines h_o, and by the formula, h_o is assured and ψ obtained. One or two trials, however, will make the assumed and computed values of stem agree.

Example: $h = 60$ $h_o w = w^1$, try $h_o = 54$, then $bh = 5^1$ and by eq. (10) $62500 + 166.7\psi^2 + 1183\psi = 17.5^*(9203) + 85349$.

∴ $\psi = 29.5$ or clear stem of $25\frac{1}{2}$ or too large.

Try

$h_o = 50$ $\psi = 25.4$ " " " " 20.4; as $(63.5 - 50)\ \frac{3}{8} = 20.2$.

This value of ψ will answer, though for safety a few feet may be added.

It is evident, if the foundation will admit of it, that the ends of head, should be vertical, as in that case $(13 + bh)$ 2d member of eq. (10) reduces to 13; as it also does in 1st member, but not with such a difference in results; for, as no part of the head can stand by itself, it is economy to make it as short as possible, thus giving less length of stem. The earth will run a little further in front of the abutment, though for a head with vertical end, eq. (10) is on the side of safety, for earth embankments are generally only 12 ft. wide at top, not 20; consequently the earth does not extend to the same h_o, all along the head of abutment, as was assumed.

14. Let us see with what coefficients of friction, the *whole head, alone*, would resist sliding from the earth pressing along $(13 + \frac{1}{12}h)$ of its length; taking earth *level* at height h; by eq. (6*) § 10.

* $(\psi + bh) = 18$ really; but (see latter part of this article). 17.5 is safe.

$Wf > P(13 + bh)$. Let $h = 36$ and $f = .5$ $\phi = 34°$, then

$$.5 \times 8 \times 23 \times 36w > \frac{.28}{2} h^2 (13 + 1\tfrac{1}{2}h)\, w^1$$

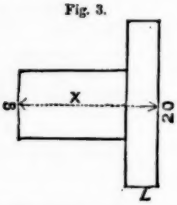
$$\therefore\ 3312w > 2916w^1$$

For $h = 48$ and $f = 6$	$6221w > 5183w^1$
" $h = 60$ and $f = \frac{3}{4}$	$10000w > 9072w^1$

So, for these values of foundation friction eq. (6*) is fulfilled—when a unit of length of head, though it cannot by itself resist sliding, the back joints are liable to open for certain thicknesses of head and ashlar work in it, for which see § 20.

15. The T abutment, Fig. 3, has vertical sides, head 20 ft. × 4 ft. and stem 8 ft. across. The stem and head are the same height, which is nearly the case in some iron bridges. Let us, as in § 12, first assume the earth level

Fig. 3.



with top of abutment; then the moment of stability of head on either side of stem $= q\,w\,h\ 12 \times 4^2$; the moment of stability of stem and rest of head $= q\,w\,h\ 84^2$: then by 2d member of eq. (2).

$$\frac{Wh\,(72 + 34^2)}{20} = W^1 \frac{(1 - \sin\phi)\,h^3}{(1 + \sin\phi)\,6} \qquad (11)$$

For $\phi = 34°$

$$\psi = \sqrt{\frac{.313h^2W^1}{W}} - 24.$$

Take $W = w^1$ as about an average

For $h = 11'.4$	$\psi = 4'$	or a clear stem of $0'$
$= 20$	$= 10$	6
$= 24$	$= 12.5$	8.5
$= 30$	$= 16.$	12.0
$= 36$	$= 19.4$	15.4
$= 60$	$= 33.$	29.

These values are a little too large, as will be seen § 17.

16. Let us compare the volumes of the two abutments, Figs. 3 and 2, taking the values of ψ, §§ 12 and 15:

				Cub. ft
For $h = 24$, abt.	Fig. 3, $\psi = 12$	5, vol.	=	3552
$h + h' = 24$ "	" 2, $\psi = 8$	"	=	3355
$h = 39.5$ "	" 3, $\psi = 22$	"	=	8848
$h + h' = 39.5$ "	" 2, $\psi = 17$	"	=	9564
$h = 63.5$ "	" 3, $\psi = 36$	"	=	21336
$h + h' = 63.5$ "	" 2, $\psi = 29$	"	=	24618

Up to about 30 ft. high the battered one is cheapest; above that height the one Fig. 3, and the saving is in rubble backing, as the ashlar is nearly the same in both. See § 20 for principal defects of this abutment.

17. The strict formula is similar to that of § 13 for this abutment, Fig. 3. Let $\theta = 34$ deg., then

$$h(72 + 34^2) = \frac{W^1}{W}\left[12\,(.114h_o^3 - .8h_o^2) + 8 \times .047h^3\right] \qquad (12)$$

For $w = w^1$

$$\psi = \sqrt{\frac{.456h_o^3 - 3.2h_o^2}{h} + .125h^2} - 24$$

For $h = 30$,

try $h_o = 21$; $4 = 15.4$, clear stem $= 11.4$

a little long

try $h_o = 23$; $4 = 14.4$, " " $= 10.4$

correct as $(30 - 23)\ \frac{3}{7} = 10.4$ nearly.

For $h = 50$,

try $h_o = 37$; $\psi = 25.8$, clear stem $= 21\ 8$
" $h_o = 36$; $\psi = 24.8$, " " $= 20.8$.

18. *Sliding.*—As in Art. 14, first, take the weight of whole head $= W$:

Wf must be $> P \times 12$,

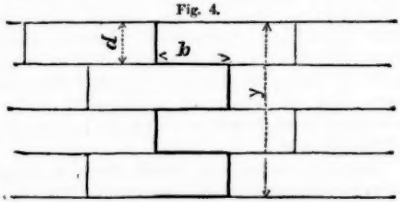
or $80xhf$ must be $> \frac{w^1h^2(1 - \sin\phi)}{2\,(1 + \sin\phi)} \times 12$.

For $\phi = 34°$, $w = w^1$, $f = \frac{2}{3}$;

When $h = 32$, sliding would just occur but for the friction from the overlapping of joints at junction of stem and head, as the tenacity of mortar should, for safety, be left out of consideration.

19. The formula for this friction is found by Rankine in the following manner: Let b=length of overlap at each joint (see Fig. 4); d=depth of one course, t=thickness of wall, supposed to overlap, and y=the depth

Fig. 4.



of joint considered. $w\ b\ t\ y$=vertical pressure or weight on the overlapping portions of the stones or bricks at the depth y, *i. e.*, on a surface=$b\ t$ at that depth. Then $w\ b\ t\ y\ f$=amount of frictional tenacity for the joint at the depth y.

The value of y for the top course $= d$.
" " " y " " lowest " $= nd$
by putting $n =$ no courses, so that $y = nd$. The mean value of

$$y = \frac{n+1}{2} d.$$

Mean frictional tenacity

$$= \frac{n+1}{2} fwbld.$$

Total amount of depth y is

$$h \frac{n+1}{2} fwbld = \frac{fwbl}{2d} (y^2 + dy).$$

For headers and stretchers alternately $\frac{b}{d} = \frac{3}{4}$ usually, and putting $f = \frac{2}{3}$. *Total amount of frictional tenacity for depth y*

$$= wl \frac{y^2 + dy}{4}. \qquad (13)$$

20. Let us consider, for abutment, Fig. 3, the horizontal thrust of earth=P $\times$ 12, opposed by the friction of head and that of the overlapping of blocks at junction of stem and head, at the variable depth y

$$P \times 12 \text{ must be} < w \left(80yf + \frac{t(y^2 + dy)}{4}\right). \qquad (14)$$

$$\text{As } \S 3 \quad P = \frac{W^1 (1 - \sin \phi)}{2 (1 + \sin \phi)} y^2$$

for $\theta = 0$ put $\phi = 34°$ $\therefore$ $P = .14 W^1 y^2$ $\therefore$

$$1.7y^2 \text{ must be} < \left[80fy + \frac{t}{4}(y^2 + dy)\right] \frac{W}{W^1}; \qquad (15)$$

For $t = 8$, or whole width of stem ashlar work, this equation is always fulfilled for $W = W^1$. Substituting $t = 4$ or half the width of stem (rubble not supposed to overlap for extreme safety), $d = .2$ for brickwork $\frac{W}{W^1} = \frac{5}{6}$. $f = \frac{2}{3}$ we find that for $y = 50$, the head would slide away and *for* foundation friction $= .4$, $y = h = 31$ is the maximum height that can be used. This should forbid brick for this abutment with a poor foundation. For granite

$$\frac{W}{W^1} = \frac{10}{9} \text{ say and for } f = .4,\ y = h \text{ must be} < 62.$$

For $f = \frac{2}{3}$ $y = h$ must be < 102.

It is plainly seen from §§ 14 and 20 that the *heads* of T abutments must increase in width *at top* as they increase in height and the preceding formulæ can establish that width for any assumed foundation f and value of t; having regard also to the following article.

21. When the horizontal thrust of earth is greater than the bottom friction on one side of stem, though less than the combined bottom friction of entire head + friction from overlapping of stem, the path of head 6 ft. long by 4 ft. wide (Fig. 3), is in the condition of a beam uniformly loaded, with a force $(P \times 6 - w \times 24\, y\, f')$ or a force

$$\left(\frac{6P - 24wyf}{2}\right)$$

applied at one end of head, tending to compress the front and extend the back of the head of the abutment; which extension force must be resisted by the friction of its courses (again assuming mortar tenacity= o). By eq. (13) considering that the lever arm of the thrust, caused by earth pressure =6, and that of frictional resistance=3, say,* and for $t=2$

$$3 \frac{wl(h^2 + dh)}{4} \text{ must be} > \frac{6P - 24whf}{2} 6. \qquad (16)$$

For $\phi = 34°$

$$\frac{3}{4} wl (h^2 + dh) \text{ must be} > 2.5w^1 h^2 - 72whf.$$

Let $w = w^1$, $t = 2$, $d = 2$, $f = \frac{2}{3}$ $h < 51$

to prevent the back joints from opening. For brickwork h will be still less and for granite more than the above value. The facts before us as to this abutment, on the supposition that the earth is level with top of head, are these: For heights about 30 ft. and rock foundation, sliding of the whole head would occur but for friction of overlapping stem; with a brick abutment and foundation $f = .4$, the whole head would slide away from stem (for $t = 2$ in eq. (15)), though for $f = \frac{2}{3}$ the height may be up to 50; for a granite abutment h may be up to 62 for $f = .4$ and with rock foundation up to 100; but §21, the height must not be over 50 about, or the back joints will open for $t = 2$ of eq. (16).

However the earth in practice slopes at ϕ angle from end of stem; therefore heights greater than these can be used and the preceding formulæ suffice to compute the effect, as the inclined thrust of earth can be resolved (§ 10) into a vertical and a horizontal component; the former adding to the friction of the base, the latter causing the sliding, if any.

This abutment (Fig. 3), though cheaper for heights over 30 ft., does not look so satisfactory as the one Fig. 2. Its width of head, however, can be increased at pleasure

* See Haupt's Bridge Construction, p. 94.

so as to conform to any condition imposed upon it by the preceding eqs. The battered abutment is generally preferred, as it distributes the same weight over a greater area of foundation. For a rock foundation this is not essential.

22. It is evident that the earth pressing against the *sides* of the stem and head of the T abutment, causes friction, opposed to overturning, and this is an advantage in any counterforted wall, over one of uniform crop section; but its amount is difficult to estimate, and prudence forbids its being included in the computation.

For heights up to 60, the proximate methods for abutment (Fig. 2), give good working values. For the abutment (Fig. 3), the strict formula had better be used and a few feet added to stem, for some unforeseen change in ϕ or foundation f.

23. When the cars run over the top chord of a railroad bridge, the part h' (Fig. 2) is usually 18 ft.—30 ft. high. Let us apply the preceding formulæ to the case of a brick abutment built years ago, which has stood the test of time and is of the following proportions (refer to Fig. 2): $h=60$ ft. $h'=19$ ft., head 7ft.$\times$18 ft. at top, stem 36 ft. long from *middle* of head; head battered 1.12 ft., $\frac{W}{W'}=\frac{5}{6}$. Use the *form* (eq. 10) putting for 5 ft. width of head at top, 7 ft., and for 7 ft. width of stem, 8 ft., h=58, then

$$(7+bh)\,(10+bh)\,(7+2bh)\,\tfrac{3}{4}h+\left[8h^{1}\,(x-3\tfrac{1}{2})+8h\,(x+\tfrac{1}{2}\,bh)\right]\tfrac{3}{8}\,(x+bh)$$
$$=[15\,(.114h_{o}^{3}-.2\,h_{o}^{2})+8\times.047\,(h+19)^{3}]\,\tfrac{6}{5}$$
$$\therefore\ 63{,}850+2374x+14364+1250$$
$$=(162{,}075+185{,}383)\,\tfrac{6}{5}$$

$x=35.4$ or stem $=32'$ long from middle of head.

So this abutment is safe from overturning.

If the head had only been battered on its face and back, then the coefficient (15) in second member above, would have been 10, as also $(10+bh)$ in first member, giving

$$47150+2374x+14364=352{,}120$$
$$\therefore\ x=33 \text{ or stem } 29\tfrac{1}{2} \text{ long}$$

would have caused an equilibrium.

To prevent the whole head from sliding, from its bottom friction alone; as the earth presses against $(10+bh)$ 15′ of it,* by eq. (5) (φ 34) f must be greater than

$$\frac{15\times.34hw^{1}}{12\times23w+23hw^{1}15}=.7^{1}$$

Reasoning similarly to § 20, calling W_1 weight of head, as § 3,

$$P\cos\phi=.34h^{2}w^{1}\ (\text{for }\phi=34^{\circ})\text{ and }P\sin\phi=.23h^{2}w^{1}.$$
$$P\cos\phi\times15\text{ must be}<(W+15\,P\sin\phi)\,f+\frac{th\,(h+d)\,w}{4}.$$

For $w=5$ $w^{1}=6$ $t=3\frac{1}{2}$ and $d=.2$ $h_{o}=h=60$, and dividing by h

$$1836<2622f+263 \text{ or } f \text{ must be} >.6$$

to prevent head sliding away from stem.

If the ends of the head had been built vertical:

$$f>\frac{10\times.34hw^{1}}{60\times18+.23hw^{1}\times10}=.64$$

to prevent sliding of head from its bottom friction alone, and f must be $>.5$, or the horizontal thrust of earth will be $>$ head's foundation friction and the overlapping friction of stem.

This abutment was in a dry place, had a good foundation of clay and needed no riprapping of bank. The pressure of earth in front of abutments assists their stability; though it is safer not to estimate it, except as adding to the stability of an otherwise equilibrated structure.

Consider a unit of length of head as regards sliding

$$f\text{ must be}>\frac{P\cos\theta}{W+P\sin\theta}=\frac{.34h^{2}w}{12hw+.23h^{2}w}$$

or f must be $>.85$, which it is not, therefore it is in the condition of a beam uniformly loaded. By § 21 to prevent back joints from opening, the resistance

$$\frac{wt\,(h^{2}+dh)}{4}\times10$$

(average lever arm) must be

$$>\frac{P\cos\phi\times7.5-(12hw+P\sin\phi)f\times7.5}{2}\times7.5,$$

as 7.5 is the lever arm of the force, for $\phi=39$

$$\therefore\ wt\,(h+d)>\frac{2\,55hw^{1}-(12w+.23hw^{1})7.5f}{2}\times3.$$

Put $h=60$, $w=5$, $w^{1}=6$, $d=.2$, $t=3.5$, then $1053>1377-1607f$ an equation fulfilled for $f>.2$. So there is no danger from back joints opening.

For t, or thickness of bonded work at back=2,600 > 1,377—1,00 > f, an eq. fulfilled for $f>.48$. With the end of the head

* The part of stem directly over head is disregarded, though its weight may be easily added to that of head, etc.

vertical there would be no possible danger from this cause.

In this way every T abutment can be examined for its weak points, the best proportion established and the proper size calculated; so far as they are dependent upon earth pressure. Thus for the above abutment the width should be greater, of the head, at top, to resist better its sliding away from stem, and, as before stated, this width should vary with the height in any abutment.

The abutment Fig. 2 can be tested for sliding in a similar manner.

24. Where, in Fig. 2, $h'=20$, $\psi=35$, and $b=0$, or vertical sides, eq. 10 will give $h=42$ about, or an abutment 62 ft. high, with a clear stem of 30 (just allowing the earth at 1½ slope to reach the top of head) will resist the earth thrust. For all *deck* bridges, however, for any height less than this, there must be a stem 30 ft. long if the earth takes its natural slope, or less with riprapping, *i. e.*, *generally* the stem is longer and costs more than is necessary. Then why not use a *through* bridge in all such cases, where there are no piers; or even one or two piers, if there is a total saving in masonry?

The "rule" is to construct a deck bridge if the grade line will admit it, though the contractor will build a through as cheaply as a deck bridge. A large number of piers, of course, require a deck bridge for economy (as their height is 18 ft.—20 ft. less), though for only one or two piers, a calculation may show a saving in the through bridge.

The earth should never be allowed to press against the planking of the bridge, as it will eventually give, and a terrible accident to the first train may be the consequence. To meet this difficulty a vertical *wall* of the same *length* as head of abutment and *height* of stem is often added to the back of head, and the stem placed to that. For h' (Fig. 2) $=20$, this wall must be 5 ft. or 6 ft. thick, if earth presses against its entire height, or less when a stem is used. For $h+h'$ (Fig. 2) $=30$ batter in front (only)$=\frac{1}{12}$ top of head 5×20, wall 6×20 on top this abutment, without any stem will resist earth pressure,* though then the earth presses against the side of the bridge, and it will take a stem of 12 with a slope of earth of 45 deg. to nearly clear it with a wall 2.5 thick (which by § 6 will do). By using this abutment, the deck bridge, over certain heights, is as cheap as the other.

Wing wall abutments give a larger waterway, greater protection to bank, but cost more than T abutments for these reasons: The *lever arms*, being reckoned, for the masonry to resist overturning, from near the front line of base and that line extended, are not so much with a wall inclined between 0 deg. and 90 deg. as in a wall perpendicular to face as the stem of the T abutment; again the whole width of bank presses, though with variable height, instead of only 18 ft.—20 ft. as in the T abutment; and, lastly, the wing walls diminish in height towards their ends.

From the first and last causes, it is evident the moment of stability is not so much as in a T abutment of equal weight, and as the total pressure is greater, we can see why the wing wall abutments for the same height take more masonry than the T abutments. A calculation alone will show which is cheapest in the end.

It is hoped the preceding will be useful to the profession in investigating the sizes and proportions of "Uniform Section and T Abutments" so far as they are affected by earth pressure.

* Apparently $\frac{120\times30\times7+20\times6\times10\times\frac{3}{2}6}{20} > .047\times30^3$

$\therefore\ 1395 > 1269.$

TIDE MOTORS.

From "Engineering."

We now propose to consider the subject in greater detail. And here we may in the first place remark that there are two ways in which a storage reservoir may be employed in connection with a tide-way for the development of power by turbines. According to the one plan, the water would be permitted to flow through the turbines into the reservoir during the flow of the tide, and the reverse way during its ebb, but a small head or difference of level being maintained between the water in the tide-way and that of the reservoir, and the turbines being thus driven almost continuously. According to the other plan, the sluices of the reservoir (the latter being

supposed to have been emptied during the preceding ebb) would be kept closed during the early part of the flood, and only opened when a considerable head of water was available for working the turbines; while, during the ebb, a similar course would be followed, the water not being allowed to flow from the reservoir until the external water had fallen to a considerably lower level. The former plan would necessitate large storage reservoirs, and turbines capable of developing the required power with a small head of water; while the latter would require smaller storage capacity for a given power (the mean working head of water being greater,) and perhaps slightly smaller turbines, but it would necessitate a vast increase in the accumulator power, as the working of the turbines would be intermittent. Notwithstanding this latter disadvantage, the last mentioned system of working is one which has not unfrequently been advocated, and it is, therefore, worth while to examine it more closely.

The 1,000 horse-power which we have taken as our standard of comparison, is the equivalent of a 1,000 indicated horse-power developed by the steam-engines which the tide motor is designed to replace; and it would probably represent, say, about 750 horse-power actually exerted on the shafting of the mill. This horse-power is, of course, represented by a considerably higher power developed by the turbines, and a still greater amount of water-power expended at the storage reservoir. To apply 750 effective horse-power to the shafting, the hydraulic engines would probably have to indicate about 1,100 or 1,150 horse-power, against the 1,000 horse-power indicated by the steam-engine, while, in addition to this, the turbines have to develop the power expended in overcoming the friction of the water in the pipes, the friction of the pumps, and the losses by leakage; while the water entering the storage reservoir and supplied from it, has to represent an amount of power exceeding that developed by the turbines to an extent varying with the efficiency of the latter. Thus, to enable the hydraulic engines to indicate 1,100 horse-power, and to exert, say, 750 effective horse-power on the shafting, the turbines would probably have to develop on the average about 1,400 horse-power, while with turbines of fair efficiency, this would represent the expenditure of about 1,800 horse-power in the water used. If we take into account the losses from leakage into and from the reservoir, and the diminution of efficiency of the turbines when working with exceedingly small heads, we can scarcely conclude that a water-power of less than 2,000 horse-power will be requisite to furnish the equivalent of 1,000 steam indicated horse-power at the mills where it will be utilized. This conclusion enables us to estimate approximately the size of reservoir required under given circumstances.

We have said that the average power to be developed by the turbines to furnish 750 net horse-power at the mill, where the power to be used would probably be about 1,400 horse-power; but this would only be true if the turbines and the hydraulic engines driven worked the same number of hours per day or per week. If the intermittent system of working of which we have already spoken, was adopted, the turbines could probably only be run run about $1\frac{1}{4}$ hours per tide, or say 33 hours in an ordinary working week of $5\frac{1}{2}$ days, while the hydraulic engines would probably run about 54 hours. The average power developed by the turbines when at work would thus have to be increased in the proportion of 54 to 33, or to furnish 750 net horse-power at the mills it would be required that they should develop

$$\frac{1400 \times 54}{33} = 2291 \text{ horse-power.}$$

The size of storage reservoir required would depend upon the rise and fall of tide and upon the system of working adopted, the largest amount of storage being, as we have explained, necessary if the turbines are driven almost continuously during both the ebb and flow. If the intermittent system be adopted, and the turbines be worked during the first and last three quarters of an hour of each ebb and flow, there are probably few places where a mean effective head of more than 10 ft. could be reckoned upon during the whole passage of the water through the turbines. Under such circumstances each pound of water entering or leaving the reservoir would represent, therefore, 10 foot-pounds of work. We have said that to supply 750 net horse power at the mills, a quantity of water representing 2,000 horse-power would probably have to be used, and this being the case, and the mills probably being run about 54 hours per week, the water entering and leaving the storage reservoir per week would have to represent $2,000 \times 33,000 \times 54 \times 60 = 213,840,000,000$ foot-pounds of work,

or taking the mean head as 10 ft. the aggregate influx and efflux would have to be 21,384,000,000 lbs. of water. If twenty-two tides (ebbs and flows) were turned to account in a working week, this would give 972,000,000 lbs. of water, or 15,552,000 cubic ft., to flow into or out of the reservoir per tide, and as the variation of level in the reservoir would probably not be more than 15 ft. or 16 ft., this would give the area necessary as about a million square feet, or, say, about 23 acres. If a less rise and fall was allowed, then, of course, the area would have to be proportionably increased.

If the turbines were driven only by the outflow of the water from the storage reservoir, and were run during the last half of each ebb and the first half of each flow, they could be worked a greater number of hours per week than would be the case under the conditions we have supposed above, and hence the average power which they would be required to develop when running would be proportionately less. But on the other hand, the intervals during which the turbines would be at rest would be increased, and hence there would have to be a corresponding increase in the accumulator power.

We shall not, however, dwell here upon the modified systems of working the turbines which might be adopted; but before bringing this article to a conclusion, we desire to say a few words respecting the cost of the pipes by which the water under pressure would, according to the system proposed by Mr. Bramwell, be conveyed from the accumulators to the points where it was utilized. And here in the first place, we may direct attention to a fact which we have never seen publicly noticed; but which is nevertheless, we have no doubt, known to many of our readers; and that is that—setting aside the allowances for corrosion, and for joints—so long as the velocity of flow remains constant, the weight of piping required to convey a quantity of water representing a given power is unaffected by the diameter of the pipes used, or by the pressure under which the water is supplied. Thus, if at a given rate of flow, and with water under a given pressure, a certain sized pipe will convey 100 horse-power, then a pipe twice that diameter will convey 400 horse-power. But the larger pipe will also be four times the weight of the smaller, for its circumference will be twice as great, and it will have to be made of twice the thickness of metal to resist the same pressure. Again, if the pressure of the water passing throug a pipe be doubled, the horse-power conveyed will be doubled too, but so also will be the weight of the pipe, as its thickness will have to be doubled to resist the increased pressure. In practice, the larger pipes and higher pressures have an advantage, inasmuch as with them the allowances which must be necessarily made for corrosion, etc., form a smaller proportion of the whole weight. On the other hand, however, with large diameters and very high pressures, the joints become a difficulty.

If we suppose a pressure of 1,000 lbs. per sq. in. to be adopted for the water used for transmitting the power from the turbines to the hydraulic engines, then a "bar" of water 1 in. in diameter moving at the rate of 3 ft. per second—as high a velocity probably as would be admissible—would transmit 4.27 horse power. Making a small allowance for friction and other cases, let us estimate the power transmitted at the rate of 4 horse power per circular inch of section of the "bar" of water; then to transmit 1,000 horse-power, the "bar" would have a section of 250 circular inches, corresponding to a pipe 15.81 in. in diameter. Such a pipe, or the equivalent number of smaller wrought-iron pipes which it would probably be found more convenient to employ, would—making allowances for the joints, etc.—weigh above 2 cwt. per ft. run, or 528 tons per mile; and taking the cost of such pipes, including laying, at but £25 per ton (and at the present time they certainly could not be got for anything like this price), we should thus find the cost of the mere piping for carrying 1,000 horse-power to a distance of one mile to be £13,200, or a sum considerably exceeding half the whole outlay which we have shown that it would be justifiable to incur to save the cost of the coal and other expenses attendant upon the developing of 1,000 indicated horse-power in a good steam engine.

We have far from exhausted the subject of utilizing tide power; but we think we have said sufficient to show, that unless under very exceptional circumstances there is little chance of that power being profitably introduced as a substitute for that obtained by the consumption of coal in connection with a good steam engine. The fact is, that the prospect of being able to turn the vast power of the tides to useful

acconnt is such an enticing one, that it uppears generally to have dazzled those who have advocated it, and prevented them from contemplating it with that due regard to the £ s. d. side of the question, that is so essential in matters of this kind.

A NEW FORMULA FOR THE LENGTH OF AN ARC.

Abstract. Translated from Zeitsc. des Ver. Deut. Ing.

We find in very few books a formula for the determination of the length of an arc when the chord and the versed-sine are given. And in the cases in which one is given, it is so complex as to be difficult of application; and besides, requires the use of trigonometrical tables. A formula is to be desired which will give a direct approximate result; and we claim that the one deduced in this article is sufficient for all practical purposes, while it is very simple, and admits of graphic construction.

The formula is: The arc-length

$$B = 2\sqrt{a^2 + h^2} + \frac{h^2}{3a}$$

in which a is the half-chord and h the height, or versed-sine of the arc.

To obtain the length by construction: The value $\sqrt{a^2 + h^2}$ is represented by the hypothenuse BD of the triangle BCD; 2 BD corresponding with the first part of the formula. From similarity of triangles.

$$Mn : AM :: CD : AC$$

or $$MN : \tfrac{1}{2}h :: h : a$$

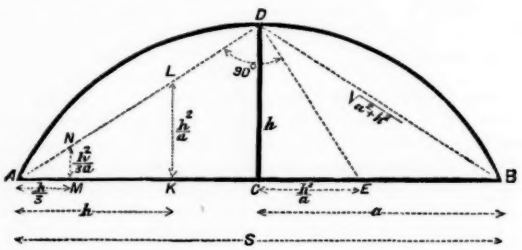
hence $$MN = \frac{h^2}{3a}$$

the second part of the formula. We may make AK=h and take one-third of KL=$\frac{h^2}{a}$. This value is represented in CE, obtained by erecting the perpendicular DE to AD.

From $$ADE$$

$$CD^2 = AC.CE$$

hence $$CE = \frac{h^2}{a}$$



A New Formula.

The following tables show the degree of exactness of the formula. In Table I. actual magnitudes are given; in Table II. are given the results obtained by the formula.

I.

Angle at Centre.	Correct Arc-length.	Half-chord.	Versed-sine.	$\frac{h}{a}$	$\frac{h}{s}$
10	0.17453	0.08716	0.00381	0.044	0.022
30	0.52360	0.25882	0.03407	0.132	0.066
50	0.87266	0.42262	0.09369	0.222	0.111
70	1.22173	0.57358	0.18085	0.315	0.158
90	1.57080	0.70711	0.29289	0.414	0.207
110	1.91986	0 81915	0.42642	0.521	0.260
140	2.44346	0.93969	0.65798	0.700	0.350
189	3.14159	1.00000	1.00000	1.000	0.500

II.

26 Angle at Centre.	B Approx. Arc-length.	B − b Error.	$\frac{1000\,(B-b)}{b}$ Ratio of Error.	$\frac{1 : B-b}{b}$ Ratio of Correctness.
10	0.17453	0 00000	0.00	.....
30	0.52360	0.00000	0.00	.....
50	0.87268	0.00002	0.02	1 : 50000
70	1.22183	0.00010	0.07	1 : 12000
90	1.57117	0.00037	0.24	1 : 4000
110	1.92099	0.00113	0 58	1 : 2000
140	2.44788	0.00442	1.80	1 : 600
180	3.16176	0.02017	6.42	1 : 150

It is seen that the results (B) are throughout larger than the actual values. The error, beginning with a value of zero, at first increases slowly, being $\frac{1}{10000}$ at 90°; while between 90° and 180° it increases rapidly. It follows that in practice the error is of no account.

SEWAGE ENTERPRISE.

From "The Engineer."

A great experiment in the treatment of sewage is about to be made by the city of Paris, or rather by the Peat Engineering and Sewage Filtration Company of London. According to the system pursued for some years past in the French capital, the fecal matters are removed from the houses in carts and wagons, and transmitted to La Villette and Bondy. In some cases the houses have movable receptacles for the purpose of holding the excreta. In other instances the cesspool principle is adopted. As far as possible the liquid is allowed to run off into the sewers, leaving the comparatively solid matter behind for removal by the carts. The movable receptacles are carted to La Villette, where they are transferred to barges which convey them to Bondy by way of the canal. The excrementitious matter which is not thus packed away is discharged from the vehicles at La Villette, and is thence pumped by steam power through a cast-iron pump to Bondy. At this favored spot the whole of the offensive matter is thrown into a number of open pits some 20 ft. deep, occupying several acres of ground. Here a precipitate is formed by evaporation and deposition, five years or more being allowed to elapse before a pit is emptied. The atmospheric evaporation creates a frightful nuisance; but vegetation flourishes amazingly, enriched by the ammonia with which the air is laden. Evaporation, however, fails to do all the work, a portion of the fluid being pumped into the Seine by a small steam-engine. The solid matter removed from the pits is first of all spread out to dry, then stacked up, and finally reduced to powder, in which state it is sold as manure. In addition to the manufacture of this "*poudrette*," the works at Bondy make a certain quantity of sal ammoniac and other chemical products; but "*poudrette*" is the principal article.

The buildings and plant at La Villette and Bondy are maintained at the expense of the Paris authorities. The contractor is paid by the householders, according to a fixed scale, for the removal of the excreta from the premises, while, on the other hand, he —or rather the contractor at Bondy—pays the municipal authorities so much per cubic metre for the matter removed. Formerly the Bondy contractor paid the authorities 1f. per cubic metre for the more solid portion, and 1f. 25c. per cubic metre for the liquid. The manufactured article of course belongs to the contractor. In reality there are several contractors or companies dealing with the Paris sewage, and they are not bound to take the excreta to La Villette unless they choose. When the tenders for the treatment of the sewage at Bondy were opened by the municipal authorities the other day, the highest price offered by a Frenchman for the semi-solid excreta was 1f. 30c. per cubic metre. Another party, not a Frenchman, offered 3f. 50c. But when the tender of the Peat Engineering Company was opened a perfect sensation was produced, the terms offered being no less than 6f. 7c. per cubic metre! An inquiry was promptly made whether the deposit money, £20,000, had been provided, and this being answered in the affirmative, the tender was accepted, the concession to commence from July 1st. It would appear that the contract now entered into relates solely to the treatment of sewage, and has no reference to the collection. The Peat Engineering Company are bound to deal with all the nightsoil brought on to theground at Bondy, the municipal council undertaking that a certain quantity shall be forthcoming, any default in that respect subjecting the authorities to a penalty of half a franc per cubic metre for the quantity deficient. It might be said that the penalty ought to be equal to the price; but of course the authorities made their own terms in regard to the penalty, and evidently never expected to get such a prodigious figure for the article they had to sell.

It is important to know how the Peat Engineering Company can expect to realize a profit on sewage matter bought at so high a price. Their plan is to treat sewage with charcoal, and they calculate that a ton of this disinfecting material is equal to the absorption of at least two tons of solid sewage matter. This they purpose to reduce to powder, packing it in bags for conveyance or storage. Their mode of treatment is just coming into operation at Bradford, in Yorkshire, where the sewage of 150,000 inhabitants, amounting to more than 5,000,000 gallons per day, including the waste liquors

of numerous dyeworks and factories, is to be filtered through charcoal, arranged in several rows of beds 700 ft. long and 4 ft. wide, each particle of sewage having to pass through 12 ft. of charcoal. The plan has been tried at the workhouse of Stoke-upon-Trent, where the flow is from 10,000 to 20,000 gallons per day, the inmates being 650. The Stoke filters are only equal to the treatment of 10,000 gallons per day, and cannot deal efficiently with the amount of fluid which accrues in wet weather. The charcoal, after doing its work in the filters, is mixed with ashes, and carted to a manure factory at Newcastle-under-Lyme. It is there treated with a mixture of sulphuric acid and ammonia to bring it up to a standard strength, after which it is reduced to powder and sold at £4 per ton. The introduction of ammonia, by which a specified strength is secured, prevents these data from being used as a clue to ascertaining the fertilizing properties of the charcoal as taken from the filters. The Company, however, are confident of success.

Nuneaton, in North Warwickshire, having been placed under an injunction by the Court of Chancery, prohibiting the discharge of its sewage into the Anker, has constructed a complete system of sewage, and has availed itself of the patent process of Dr. Anderson, as carried out by the General Sewage and Manure Company. The process is very much like that of the A. B. C. Company, only without the B. and the C. An aluminous shale is treated with sulphuric acid, so as to produce a crude sulphate of alumina. The sewage is admitted into tanks, and the sulphate of alumina, dissolved in water, is then thrown in, followed by a little slacked lime. Sulphate of lime is formed, and the alumina is set free. Precipitation follows, and the water being run off, the mud is discharged into baskets of galvanized iron wire lined with flannel, which act as strainers. As these baskets become filled with mud they are lifted by means of cranes, and the deposit is thrown on to a floor of sheet iron heated from beneath by hot air from a small furnace, the same hot air being also drawn back over the surface of the mud, and carried into the flue of the engine furnace, with a view to prevent any disagreeable odor. The dried mud forms the manure. Dr. Anderson asserts that at Nuneaton he can produce a ton of manure at a cost of 15s., or from 8 to 10 tons per week at a cost of £7, including everything. The works are put up at the expense of the local Board of Health, and cost nearly £5,000, the Sewage Company paying only £10 a year rent. The population is 7,000, and the average daily flow of sewage nearly 200,000 gallons. There are scarcely any water-closets in the town, but factories, tanneries, and mills, together with the house-washings, make a tolerably foul sewage. If there were more water-closets there would be more water, and the sewage might be none the richer—a fact of some consequence in relation to the earth-closet system. That a town with less than twenty water-closets should have an injunction against discharging its sewage into the adjacent river is rather a startling fact. But for the injunction, Nuneaton might never have been sewered. The town has been sewered in order to bring all the noxious fluids to one point, there to be dealt with as may be thought best. In order to secure the purity of the effluent water, the Sewage Company propose taking two acres of land to act as a filter. With regard to the quality of the manure, the material at Nuneaton is said to show a value of £2 per ton, according to chemical analysis, and its agricultural value is expected to be higher. The manure is calculated to contain about 20 per cent. of foreign matter and 80 per cent. sewage, the foreign matter being chiefly sand and water. In the A. B. C. manure of the Native Guano Company the sewage matter forms about one-half. The manure of the Phosphate Sewage Company —another claimant for the honors of precipitation —is enriched with phosphates on the basis of sewage, and, therefore, commands a higher value. On the other hand, General Scott proposes to burn the organic matter of sewage as so much fuel, to aid the calcination of the deposit, which he thereby converts into Portland cement. General Scott precipitates the suspended matters by adding clay and lime to the sewage, thereby providing a portion of the materials for forming the cement. Omitting the first outlay, as also the wear and tear of plant, General Scott calculates on a profit of £1 or £1 5s. per 1,000,000 gallons of sewage. At this rate the Nuneaton sewage would only clear about 30s. per week, as compared with Dr. Anderson's estimate of £9 to £13. How far the

General Sewage Company may be able to verify this latter estimate, remains to be seen. In either case the effluent water is available for irrigation.

ARTIFICAL STONE.*

By FREDERICK RANSOME, A.I.C.E.

From "Engineering."

The progressive development of the natural world, through periods which occurred long before the dawn of the most remote traditions of antiquity, have placed at the disposal of man materials which for the most part eminently subserve the varied purposes of construction and decoration. These materials, however, such as the granites, marbles, sandstones, limestones, etc., occur in isolated groups, in some instances so remote from the centres of civilization as to render the employment of them prohibitable for general use, excepting in local situations. The requirements of man, at an early period of his history, demanded a material which should approximately fulfil the conditions of stone, and this necessity was in the earlier ages supplied by the manufacture of bricks, concrete, etc. The advantages afforded by these substances were readily recognized by the ancients, and have been fully appreciated in modern times; but great as these advantages are in a constructive point of view, they fall very far short of the requirements of the present age.

It is therefore no matter for surprise that numerous attempts have been made, from time to time, to supersede the productions of nature by the imitations of art, and the importance of producing a material combining all the advantages, without having the defects, of the most useful building stones, and possibly possessing attributes peculiarly and specifically its own, was recognized many years since by the author, who set himself the task of solving the problem of manufacturing an artificial stone which should economically answer the varied purposes of the productions of nature.

His investigations into the nature and properties of stone commenced nearly 30 years since, and he found that, with few exceptions, the hardest and most durable stones were those which contained the largest proportion of silica. After numerous attempts at combining crystals of sand with powdered glass under hydraulic pressure, and uniting the mass by partial fusion; and after having exhausted the combinations of these substances with the various cements, it occurred to the author to substitute a concentrated solution of silicate of soda or potash for the other cementing materials he had previously employed.

This solution of silicate of soda or potash being mixed with sand, and pressed into a mould, formed when dried a very hard stone, having a close and uniform texture, but which, however, disintegrated upon being exposed to moisture. The next step was to submit the compound to the action of heat, when the free alkali of the cementing silicate combined with an additional quantity of the silex of the sand, and produced an insoluble silicate unaffected by moisture. In the course of time, however, the efflorescence of a salt was observed to form on the surface of the stone in buildings where it had been used. This, for the most part, proved to be sulphate of soda which existed originally in the soda ash used in the manufacture of the silicate. This objection was removed by treating the solution of soda with caustic baryta before using it in the preparation of the silicate.

Such in general were the results the author had obtained by the year 1859, when he had the honor of placing them in detail, together with his experience in the preservation of stone by soluble silicates, etc., before the Chemical Section of the British Association at Aberdeen. At the invitation of the President of the Mechanical Section of this meeting, he again appears before the Association, in order to place before its members a description of such alterations and improvements as he has introduced in the process of manufacture since his previous paper was read, and which have led to its increased usefulness both in the constructive and decorative arts.

The process of the manufacture of the so-

* A paper read before the Mechanical Section of the British Association at Brighton, 20th August, 1872.

lution of silicate of soda has been so fully and frequently described in various scientific journals that the author considers it unnecessary to do more than simply allude to it here. Ordinary flint stones are subjected to the action of a strong solution of caustic soda in cylindrical boilers or digesters under steam pressure of from 60 lbs. to 80 lbs. to the sq. in. Under these conditions the flint is rapidly dissolved by the solution of caustic soda, and silicate of soda in solution is produced, which, after being discharged from the boiler, is concentrated by evaporation to a specific gravity of 1,700 deg., and contains about 66 per cent. of silicate, 33 per cent. of soda.

In manufacturing the stone the silicate is thoroughly incorporated with clean, dry sand and other suitable silicious or earthy ingredients, in a mixing mill specially constructed for the purpose, when the compound assumes a stiff, pasty consistency, is readily pressed into moulds of any required form or pattern, and is capable of receiving and retaining the most delicate impressions. If now the mass be allowed to dry gradually at an ordinary temperature, it will become hard, and to all appearance a perfect sandstone; but inasmuch as the several particles of sand, etc., are combined together by a soluble silicate, if exposed to the action of water, the silicate will soon become redissolved, the sand and other ingredients will be set free, and the mass entirely disintegrated.

The next problem to determine was how to convert the soluble silicate of soda into some insoluble silicate, which should possess the properties requisite for the formation of a good, hard, compact and durable stone, without the action of fire heat, which had been found so inconvenient and expensive in its application in former methods.

In the year 1861, in consequence of the premature decay of the stone of the Houses of Parliament, a committee was appointed by the Government to examine and report on the causes of such decay, and the best means of preserving the stone from further injury. The author, in common with others, was summoned to give evidence on the subject, having for some years previously been engaged in working a process patented by himself for preserving stone by first saturating it with a solution of silicate of soda, and afterwards applying a solution of chloride of calcium, which immediately decomposed the former, and produced an insoluble silicate of lime in the stone so operated upon. In order to demonstrate conclusively the efficiency of such application, he proposed to reduce a piece of stone to powder, and then by the aid of these two solutions to re-convert the powder back into a solid stone.

The experiment was tried, and the result was so completely successful that a patent for the manufacture of artifical stone by the employment of these ingredients was at once obtained, and arrangements were made for carrying out the same upon an extended and practical scale. In doing so, the mixture of sand, silicate, etc., when moulded as previously described, was immediately removed to benches placed over open tanks, or immersed therein, and completely saturated with a solution of chloride of calcium. This operation in cases of large masses is materially assisted and accelerated by aid of air-pumps, etc. Double decomposition of the two solutions of silicate of soda and chloride of calcium immediately takes place, resulting in the production of an insoluble silicate of lime, firmly uniting and enveloping all the particles of which the object under treatment is composed, and a solution of chloride of sodium or common salt, which is subsequently removed by the free application of water.

The foregoing is a brief history of the material manufactured by the author down to the year 1870, when he developed another process, as distinct from the last described as that is from the process explained to this Association in 1859.

It was found in practice that the process of washing so as completely to remove all trace of the chloride of sodium from large masses of the stone was open to objection; it was both tedious and expensive, especially in localities where there was a difficulty in obtaining a good supply of tolerably pure water at a reasonable cost.

The author then conceived the idea of obviating this washing process by producing the insoluble silicate of lime without the formation of the chloride of sodium or other soluble salt, which would require subsequent removal. Step by step, this result has at length been arrived at, and the process of manufacture thereby materially simplified, the cost of production reduced, and the application of the material considerably extended. Many gentlemen present will doubtless recollect that, some years since, a silicious mineral was discovered at

the base of the chalk hills in Surrey—especially in the neighborhood of Farnham—possessing some very peculiar properties, amongst others that of being readily soluble in a solution of caustic soda, at a moderately low temperature. Taking advantage of this peculiarity, the author commenced a series of experiments, in order to determine if it were not possible, without the use of chloride of calcium, to produce a stone in all respects equal in quality to what had hitherto been done, and in this he has now succeeded.

By this latter process he combines a portion of the Farnham stone, or soluble silica, with a solution of silicate of soda or potash, lime (or substances containing lime), sand, alumina, chalk, or other convenient and suitable materials, which, when intimately mixed, are moulded into the required form as heretofore, and allowed to harden gradually, as silicate of lime is formed by the combination of the ingredients present. The mass then becomes thoroughly indurated and converted into a compact stone, capable of sustaining extraordinary pressure, and increasing in hardness with age.

The chemical actions which affect these results appear to be as under. When the materials are mixed together, the silicate of soda is decomposed, the silicic acid being liberated combines with the lime, and forms a compound silicate of lime and alumina, while a portion of soda in a caustic condition is set free. This caustic soda immediately seizes upon the soluble silica (from Farnham), which constitutes one of the ingredients, and thus forms a fresh supply of silicate of soda, which is in its turn decomposed by a further quantity of lime, and so on.

If each decomposition of silicate of soda resulted in the setting free of the whole of the caustic soda, these decomposing processes would go on as long as there was any soluble silica present with which the caustic soda could combine, or until there ceased to be any uncombined lime to decompose the silicate of soda produced, the termination of the action being marked by the presence in the pores of the stone of the excess of caustic soda in the one case, or of silicate of soda in the other. In reality, however, the whole of the caustic soda does not appear to be set free each time the silicate of soda is decomposed by the lime, there appearing to be formed a compound silicate of lime and soda, whereby a small portion of the latter is fixed at each decomposition. The result is that the caustic soda is gradually fixed, and none remains to be removed by washing or the other process.

Having explained the manufacture and chemical composition of the several descriptions of artifical stone herein alluded to, it will be as well in the next place to point out some of the varied purposes for which they are peculiarly adapted. The primary conditions of materials for construction are unquestionably strength and durability—those of a secondary nature being appearance, facility of application to the intended purpose, and economy in use. As regards strength, the value of the artifical stone herein described increases with age. By some experiments which were made for the purpose of testing their possession of this quality, numerous samples were proved, within a month of their manufacture, to be superior to Portland stone. At the age of 10 weeks, in stones made by the last-described process, the strength as compared with Portland stone was found to be as 7,145 lbs. to 2,630 lbs. per sq. in., and as compared with Bramley Fall, 7,145 lbs. to 5,120 lbs.; and as regards granite, 7,145 lbs. to 1,200 lbs. per sq. in. With reference to durability, the artificial stone has been found practically to withstand the atmospheric changes of various climates, having been exposed to the cold of Russia and the heat and rains of India. In general appearance, the stone manufactured by these processes bears such a perfect resemblance to the best description of natural stones as to mislead the most critical observers, whilst the facility of application and its economy in use will have been apparent from the foregoing description.

By means of the last-mentioned process, the field has been widely extended for the application of the stone produced thereby, and which for convenience, as distinguishing it from all others, has been termed Apœnite. It is now no difficult task to produce blocks of this material of any form and of any size, the only limit being the means available for handling them upon the spot where they are to be employed. Moreover, the materials which form the bulk of apœnite are, as a rule, generally to be found in abundance where hydraulic or other important works are being carried on, and for which purposes the new stone is eminently suited.

The want of such a material for such a purpose has long been felt, although that

want, until recently, has only been partially supplied. In 1870 Mr. J. W. Butler applied for and obtained a patent for improvements in the application of Concrete to Structures and Foundations, also to Coffer-dams and similar constructions. Mr. Butler's obvious desire was in the first place to provide a cheap and efficient substitute for stone for hydraulic operations, and in the second to render unnecessary the construction of false works, etc., and thus to avoid the expense connected with the employment of iron cylinders, hitherto so extensively used. The idea was certainly an excellent one, but its realization appeared to Mr. Butler very remote, until it occurred to him that the material then introduced under the name of "Apœnite" would answer the purposes of his proposed methods of construction. He accordingly communicated with the author upon the subject; and with the sanction of the engineer, a set of hollow cylinders 8 ft. in diameter and 9 in. thick were made to form a part of a retaining wall to protect the foreshore of the Thames at Hermitage Wharf, where they were accordingly sunk, and the result was satisfactory.

In one arrangement proposed for economically carrying out this class of work a timber staging is erected, upon which the materials may be mixed and moulded, the moulds consisting of an inner and outer framing, the space between the two forming the mould for each ring of a cylinder or hollow block, as the case may be. The courses are joined by means of a cement formed of similar materials to that of which the rings or blocks are composed. These are lifted from the staging on which they have been made, and lowered into position by an overhead traveller or crane, as may be most convenient. The lowest course is chamfered, and when necessary from the nature of the soil, may be shod with iron. The operation of sinking is carried out generally in a precisely similar manner to that adopted with iron cylinders. The horizontal joints are made with alternate projections and depressions, and the several courses are connected vertically by dowel piles, which also serve as guides in sinking the work. The application of this principle is capable of modification to suit almost every variety of construction, and it will be found especially applicable in structures requiring heavy foundations, particularly where the ground is uncertain.

For forming a face-wall in building quays or docks, instead of cylinders, rectangular hollow blocks or caissons may be used. By employing hollow blocks of hexagonal form no interstices are left, a thin layer of the cemeting material rendering the structure practically homogeneous. Cylinders constructed upon this principle are also adapted for deep wells, apertures being formed in the sides for the admission of water.

Turning to works of greater magnitude, it will be seen that apœnite forms a suitable substance for the construction of bridges, sea-walls, piers, and similar undertakings. Such structures could be carried up to the underside of the bridge girders, or built with ordinary masonry above high-water level. For sea-walls or piers another arrangement could be adopted, two rows of caissons being employed, separated from each other longitudinally, the intermediate space being filled in with dry rubble hearting, and the blocks themselves with a similar material, or if necessary with concrete.

In the case of an embankment for a reservoir, the heart of the bank, which is usually made with a puddle wall, is proposed to be substituted by two rows of cylnders, the contained spaces being filled in with puddle, and the cylinders themselves with material similar to that of which the bank is made. In sinking the cylinders, they would be carried some distance below the natural surface, so as to obviate any chance of leakage below.

Should a leak occur above, it could be only to a very small extent, as it would be prevented from extending by the proposed structural arrangement. It is obvious that this plan could without much difficulty be applied to embankments already constructed where there was reason to apprehend that any settlement had occurred. By sinking the cylinders from the top through the puddle bank, but without removing any of the slope on either side, they would be carried down to sound ground, rendering the embankment safe, and removing all fear of danger in the future.

It would not be difficult to multiply the instances in which this material can be practically applied; but sufficient has been said on this point. An artificial stone combining the advantages of apœnite—one, moreover, which can be so readily moulded into any form and size with but small expense and little or no delay, is necessarily

applicable to a great variety of uses. The author will, therefore, only briefly remark upon its applicability for ornamental and decorative purposes.

Besides possessing the several properties which have been described, the apœnite, when prepared with suitable materials, is capable of receiving the most delicate impressions, and by the incorporation of various metallic oxides, any variety of color can be imparted to it.

By the use of the native red oxide of iron, manganese, and other mineral substances, artificial marbles or granite of almost every description can be produced. These artificial stones, like their originals, are capable of taking an excellent polish, are extremely hard, and can be readily moulded into the most elaborate forms, at a very small cost.

In conclusion, the author submits that, both constructively and ornamentally, apœnite is eminently fitted to meet the numerous requirements of the engineer and architect, and to subserve many useful and important purposes in the industrial arts.

ADVANTAGES OF STEAM ROLLING FOR THE REPAIR OF ROADS.

From "The Builder."

The following is from the report of the Chief Surveyor to the Board for the Borough of Hackney, England, on steam rolling:—

The process of repair, as compared with the old system, involves the lifting of the top surface of the road, so as first to put the road into form. It is then covered with broken granite, averaging in the cases named from 1¼ in. up to 6 in. in depth. After one or two turns of the steam roller, the material is covered with fine gravel or granite siftings; the road is then watered and the sand swept in. The water cart thereafter continues to precede the roller, until the mass of material is sufficiently consolidated.

The results of this mode of repairing roads are: First, their immediate fitness for use, presenting a uniform and firm foothold for horses, and a smooth surface for vehicular traffic. The difference in driving over a road thus repaired, as compared with the old system, can be both seen and felt.

The general condition of the road surface thus repaired, when it begins to wear, exhibits a close series of small hollow places on the portions subjected to the greatest wear from the traffic stream; whereas, the surface of roads repaired in the ordinary way, presents large hollow places which occur at very irregular distances. It is, however, possible for a road repaired by means of the roller to wear in like manner, by a careless formation of the road, or spreading of the materials, or both.

The second important result, as arising from the use of the steam roller, is that of the economy of the materials used in the repair, and also the labor expended on the road.

Under the ordinary system, the granite is left loose on the road surface until pressed and bound down by the traffic; but long before the materials get fixed in place, the angles are rounded off, and a considerable portion of the stone is ground away. The vehicles also displace the loose material and form ruts in the chief line of traffic, so that it becomes exceedingly difficult to keep the road in proper form, and the road quickly becomes as defective as before.

In excavating for the purpose of constructing the North Metropolitan Tramway, the section of the road crust is exposed on each side, and several sample stones were obtained from the under or lower section (which formed the road before the repairs were carried out by the aid of the steam roller).

An examination of these will show, in some cases one, others two, or even three distinct worn traffic faces, showing that the stones were several times shifted from their bed before being finally fixed. The sample surface stones were carefully removed from the top edge of the road crust that had been repaired in the ordinary way, and as left by the excavation for the trams. Their condition proves the rough and violent action to which they had been subjected before settling down in their places. At the same time surface stones were obtained that had been fixed in their respective positions by the action of the steam

roller. The portions rubbed and abraded by the traffic can easily be detected; all the other parts of each stone have their angles and rough faces preserved intact, and had left their exact impress in the beds from which they were taken.

Certain narrow parts of the rolled road, which formerly required three dressings of new material in a given time, now require but one only.

From observations carefully taken, it appears that in 64½ days and 23 nights the steam roller finished 671,216 superficial yards of roadway, at an outlay of £493 18s. 10d. (about 1¾d. per yard), while the cost of materials and other labor for which this expenditure was incurred amounted in the aggregate to £4,802 4s. 2d., or 1s. 5d. per yard.

The cost per yard super varies from 1s. 1½d. to 1s. 10½d., and for rolling from 1.57 farthing—say 1½ farthing—to 2½d. .37. It would seem that the roller can be worked at less cost per yard on the wider roads, although both in wide and narrow roads the cost will increase in proportion to the thickness of new materials used.

The cost per day, on hire, has varied, for the parish of Islington, from £3 10s. 10d. to £4 10s. 6d., including all working expenses, water carts, water, watering, fuel, etc. The steam roller is now their own property, and is worked for about £1 12s. per day, exclusive of watching and water; or about £2 10s. per day, as against £4 10s. 6d.

At S. George's, Hanover square, the expenses of working the roller are stated at £1 11s. 8d. per day, and the Surveyor further states that the sum provides for water carts, two men, and fuel, and that he finds the roller invaluable, as it will immediately consolidate 1,000 superficial yards of new-coated granite roads per day. He further states his firm belief that economy in road maintenance will be effected by its use, and that public opinion would prevent its discontinuance.

The Board of Works for the Poplar District has had Aveling & Porter's steam roller on hire, and the Surveyor has kindly furnished the particulars of the cost of each road rolled during a period of 88 days.

On computation, the aggregate given in the first list is 15,146 yards super rolled in 17 days, at an outlay of £46 19s. 1d., or 2.98 farthings—say 3 farthings per yard= £2 3s. 6d. per day, while the repairs cost £716 19s. 4d., equal to 11¼d. per yard.

The second list gives 45,699 yards during 71 days, at an outlay of £2,747 11s. 2d. for repairs, or half ¼.61 per yard, and £183 10s. 1d.—3.98—say 1d. per yard super= £2 11s. 6½d. per day.

The process of working, however, differs in some of the roads in Poplar from that of Islington. In lieu of the covering of sand, washed in by the water cart, a thin layer of road sweepings is spread over the road, and the new granite laid thereon. The extreme weight of the roller presses the stone into the soft bed; and, if found necessary, a little water is added, and the softening is then worked up to near the surface of the road in the process of rolling.

Of course, this is much cheaper as a first outlay, but having inspected both the Islington and Poplar roads, it is suggested that the soft bed may continue for some time to exude through the joints of the stones under the traffic, and keep the road, in damp weather, in a dirty state. This may occur even with an appearance of soundness, and if this theory be correct, this system will tend to weaken the road; but, on the other hand, the stones may, by the rising of the soft bed, be brought into close contact, because of the fineness of the particles. It could be easily tested, by repairing in the two modes a length under each system, in one line of thoroughfare. The saving is considerable, if effective, and is, therefore, worth the experiment.

New rollers are required about twice in a year, and other parts of the apparatus require renewal in from five to seven years, and its first cost is £550. The roller is capable of rolling on the average 700 or 800 yards per day.

The horse roller at work in this district costs £1 4s. per day, and as a question of comparison between the horse and steam roller, I am of opinion that a steam roller will do more good in three turns over the road, than the horse roller will do in twelve.

The first coal ever mined in the United States was dug near Richmond, Va. Bituminous coal was mined there as early as 1700, and in 1775 was extensively used in the vicinity. During the Revolution a Richmond foundry employed this coal in making shot and shell for the use of the Continental forces.

PORTABLE ENGINES

From "The Engineer."

The portable engine trials of this year at Cardiff are looked forward to with no small anxiety by the whole community of agricultural engineers. Firms which have always taken high places must be prepared not only to encounter keen rivalry among themselves, but to do battle with some outsider who may blow all their fond anticipations of a new triumph to the winds. The chances are all in favor of the older firms, however, and it is worth while to explain why.

The construction of a portable engine which shall run for even three and a-half hours on the brake, with an allowance of 14 lbs. of coal per actually effective horse-power, is by no means an easy task. To make an engine which will under the same conditions run for four hours and a-half is a work of really enormous difficulty. It can only be solved and we have no hesitation in saying this, by those who have devoted a lifetime and a fortune to the work. The theorist is utterly at a loss here. He may be perfectly right in his reasoning. The accuracy of every law upon which he acts may admit of the clearest definition, but without enormous experience he is certain to fail in reducing these laws to practice, and in combining them in one harmonious whole. For example, we have again and again seen portable engines fitted with cylinders perfectly jacketed all over, expansion slides, excellent boilers fed with water at 212 deg., friction reduced to a minimum, and, in one word, every resource that science can suggest employed to secure a successful result, and yet not more than a three hours, or three and a-quarter hours run could be got out of them. Ask the theorists why ? and he is at a dead loss. All the conditions he can dictate have been complied with, and yet, in such a contest as that impending at Cardiff, his engine would be nowhere. Ask the practical builder of racing engines the same question, and he replies at once that "the engine is wrong all over," "that there is no part in her right;" and that he is correct in his statement he proves by bringing to the brake an engine externally the same, possibly by no means so fully complying with the dictum of the theorist, and with this engine he distances all competitors, and runs four hours and a-half or even more. Those who fancy that we can explain on what success depends in constructing a racer, will, we fear, be disappointed if our explanation is to include a dissertation on proportions and dimensions, and cut-off valves, and pistons, and boilers. The art of constructing racers is an art not written, and impossible to write. But we can explain the nature of the process by which a racer is constructed, and the means adopted in securing a successful result when once the design has been prepared and the engine constructed.

It is of course known long beforehand that a portable engine competition is to take place. The general conditions of the trial are also known very early. These conditions are prepared with the utmost regard for the interests of those who are the principal purchasers and users of portable engines. The moment the conditions are made public the intending competitor commences to prepare a design—or, it may be, to modify a design already prepared so as to make it comply with the conditions. Thus a good 10-horse design might be ready which will not suit without alteration if the competitor be limited to engines of 8-horse power. In preparing this design the competitor who really knows what he is about is guided almost entirely by experience. If he introduces any novel device, he takes care so to introduce it that it can be discarded, if need be, in favor of some other expedient to secure the same end already well known and fully tried. As for the teachings of theoretical science, they are but little studied. A jacketed cylinder is used as a matter of course; but science teaches nothing as to how the jacket is to be made, or what the thickness of the cylinder inside should be. The steam is used expansively, of course. Theory says, expand as much as possible, but practice tells a very different story; so the grade of expansion is always made adjustable in the first instance.

In designing the boiler the same principle is adopted. Theory says that the largest possible heating surface and slow combustion should be adopted; but practice has proved that there is a certain rate of combustion best for each boiler, which can only be determined by experiment, and to

which theory gives no clue whatever, so the grate is always made large enough to admit of adjustment.

At last engine and boiler are complete—say, if all goes well, about December. The engine is then taken to a special shed, and set to run on a brake as precisely similar as possible to the brake used by the Agricultural Society. She is then run for some days without thought of the duty, just to get everything down to its bearings, and to see that all works smoothly without heating or discomfort. Then commences a series of trials usually extending over months, during which a host of experiments are carried out to determine the best speed, the best point of cut-off, area of grate, calorimeter of tubes, etc. The labor involved in these tests must be experienced to be credited. They demand all the patience as well as skill that a man can display. One week it is found that the engine does very well—an apparently insignificant change is made in a minute detail, and the engine does much better. The alteration is pushed a little further, and all the good that was done by the first change is undone by the second. So the work goes on with varying success, until at last a point is reached beyond which it is found to be impossible to go. A racing portable engine of the first class is, whatever a few carping critics may say, one of the most perfect embodiments of mechanical genius and skill in the world.

The manufacture of portable engines constitutes an enormous trade in this country. English portable engines are sent to every portion of the known world. There is not in existence a more enterprising body of men than the agricultural engineers of Great Britain. Our readers may rest satisfied that the leading firms have discovered very excellent reasons for the proportions they have adopted, the speeds at which their engines run, and the pressures to which they load their boilers.

ROLLING vs. HAMMERING INGOTS.*

From the "Railway Times."

In order to put sufficient *work* on steam ingots for rails, they must be reduced from about 12 in. sq. As this cannot be done at one heat, they are first drawn down to about 7 in. sq., and then reheated and rolled into rails. The first reduction or "blooming" is usually done in this country in a 30 in. 3-high rolling mill, with movable rolls, so as to get several reductions in each set of grooves. The first of these mills has been running at the Troy Steel Works above a year, with great success. Another at the Cambria Iron Works has been running about six months and has produced 140 tons of rail blooms from 12 in. ingots in 24 hours. The mill was not then fully employed, the limit of capacity being a single Siemens heating furnace.

The practice is now being introduced of rolling long 12x14 in. ingots, instead of short 12x12 in. ingots, thus producing three rail blooms at one rolling instead of two, and saving largely in labor and fag ends. As the handling of the piece at the rolls, and indeed its charging and discharging at the furnaces, are performed by steam power, the large ingot requires no more men than the small one. The capacity of a blooming mill, rolling 3-rail ingots, may be safely put at 200 tons per day.

In England, and also at the Pennsylvania Steel Works at Harrisburg, the rail ingots are reduced to blooms by hammering, usually 10 to 15 ton hammers. The 13 ton hammer at Harrisburg is a first class tool, and the practice with it is usually good. Its maximum production is about 75 tons of blooms per day, or much less than half that of a rolling mill which cost, with its engine, about the same money. A smaller number of men and less skilled and high priced men are employed at the rolling mill. By the use of Mr. Fritz's feeding tables the labor at the rolls is reduced to little more than directing the operations of the machinery.

Three-rail ingots cannot be advantageously hammered under a hammer.

The impression has heretofore existed among railway men that the quality of what they call hammered rails is superior to that of rolled rails. The use of *rails* has not developed this impression so far as can be ascertained. The impression is not founded on the fact that *iron* is improved by hammering, and that the highest priced

* From a paper read before the American Institute of Mining Engineers, February, 1872, by A. L. Holley, Esq.

steel—such as tool steel—is hammered rather than rolled.

It is true that the pressure of the hammer is greater and more concentrated than that of the *light rolls usually employed*, and that the hammer may expel more cinder in early stages of *iron* manufacture. The real reason why the hammer is used in iron mills, however, is because it will work large and hard puddle balls and piles for which there is no adequate rolling machinery at hand. That rolls are preferred to hammers, even for iron, in the most improved practice, is shown by the introduction of very heavy squeezers instead of hammers, for reducing the large puddle balls of the Danks furnace.

The hammer certainly increases the density of the iron or steel bar, as compared with rolling. The rolls crowd the fibres back, as well as towards the centre; the action of the hammer is exclusively towards the centre. This is conspicuously shown in treating large ingots. The velocity of the hammer is greater than that of the periphery of the roll; hence the effect of its impact is greater on the *surface* of the ingot, while that of the rolls is more distributed throughout the thickness of the ingot. It would therefore be supposed that the hammer would *draw* the surface of the ingot so much as to leave concavities in the ends. The rolled bloom is cup-ended, *although* it is more uniformly condemned than the hammered bloom. The result of this must be, and the fact is, that the rolled ingot is less dense; it weighs less per cubic inch, but at the same time it is more uniform in structure. Now this density does not promote toughness in *steel*, whatever it may do in iron, while uniformity *does* promote toughness, and this is the quality to be most carefully looked after in the steel rail manufacture. Nearly all steel rails are hard enough for wearing purposes, and their hardness can be increased by chemical means, and with the greatest uniformity and convenience—indeed the trouble is to sufficiently keep down phosphorus, silicon, and other hardening agents.

It is stated that the carbon in hammered steel is chemically combined, while that in rolled steel is graphitic. If this is the fact in regard to rails, it is a strong argument in favor of rolling. As we have just observed, steel-makers with the irons they have find difficulty enough in making their rails mild and tough, without being subjected to the additional embarrassment of chemically combined carbon. It is well known that the tool-maker's process of hardening is simply combining the carbon, while *annealing*—that safety process to which boiler plates and forgings are subjected to give them toughness, consists in simply rendering this carbon graphitic—the same thing that rolling is said to do.

But, in fact, rail-makers are not embarrassed by the hardening process imputed to hammering, because there is no such thing as a hammered rail, or as a structural condition of rail due to hammering. Whatever the condition of carbon in a hammered *bloom*, it is graphitic in the rolled *rail*. The reheating of the bloom, and its subsequent treatment by rolling alone, probably leave the physical condition of the steel substantially the same as if it had been rolled rather than hammered *before* reheating—excepting only the condition before mentioned, due to the character of the pressure—the rolled steel is less dense, and is more uniform. This uniformity is further increased by the fact that the temperature of a rolled ingot is practically the same at each pass, while the hammered ingot is reduced at varying temperatures.

A very large number of experiments have been made at Troy and Johnstown, on rolled and hammered ingots from the same steel, and although the results confirm the above reasoning, rather than contradict it, the difference in the quality of the rails is not very marked. In fact, a large number of rails rolled direct from 9 in. ingots are wearing as well, so far (three years), as rails made from either hammered or rolled 12 in. ingots. In making *complete* tests—tests to destruction—it is unnecessary to say that the size of the ingots experimented on by the hammer and the rolls should be the same. A test in which rolled 9 in. ingots are compared with hammered 12 in. ingots has no value.

The use of hammers or rolls for blooming seems to resolve itself, then, into a question of cost of product, as it has been impossible to establish, so far, any marked difference in quality—certainly none in favor of hammering.

We have shown that the rolling mill has over twice the capacity for a given cost, and that it employs less labor. Another advantage of the rolls is, that their collars hold up the corners of the bloom, thus reducing its cracking, and making sounder

rails, as well as a larger number of first quality rails from a given number of ingots. Rolled blooms are of exactly uniform cross section, while hammered blooms must vary considerably. Hence the crop ends of the former may be reduced to a uniform minimum, while a large allowance must always be made in hammering.

THE GREAT WESTERN SUBMARINE TELEGRAPH CABLE.

From "Engineering."

During the progress of the manufacture of the Atlantic cables of 1865 and 1866 the public were constantly informed of the various details of the work and of all that was going on. Excitement was then high, and the problem of deep-sea cable laying was a questionable point, rendered subsequently still more so by the failure of the 1865 cable.

In the following year the successful laying of the 1866 cable, succeeded by the great event of the recovery of the lost cable of the year before, and its being connected across the Atlantic by the addition of an extra length of cable, completely changed affairs. Deep-sea cable laying was a success, the problem of submerging a cable in deep water, and also the possibility of its recovery, was perfectly and satisfactorily solvet.

The success attending Atlantic telegraphy has made people express wishes for more cables and reduced tariffs—the latter being so high as to be somewhat exclusive; and to enable the public to send messages at a less rate, the Great Western Telegraph Company was projected for the purpose of laying, during the course of next year, a cable from England to New York via Bermuda. This endeavor so far succeeded that the public took the matter up, and a contract was signed for the manufacture and laying of the cables, which are now in course of construction.

The proposed route for the cable is entirely new. The cable will start from a convenient point at the Land's End to the island of Bermuda, and from thence to New York. From Bermuda a cable will in the course of time be laid to St. Thomas to connect with the network of West Indian cables, and there are subsequent intentions of connecting Bermuda with the coast of South America, which route is stated to possess the great advantages of connecting Brazil with England and with New York by direct lines.

Necessarily the form of cable will differ with the nature of the sounding; the amount of the cable of the several types required will vary also as to the distance these soundings may be expected to be met with. These distances may be particularized as follows:

Section 1, Land's End to Bermuda:

		Knots.	
Main cable,	type A	2,990	
Intermediate cable,	" B	210	
Shore end,	" C	25	
			3,225 knots.

Section 2, Bermuda to New York:

Main cable,	type D	642	
Intermediate cable,	" E	40	
Shore end,	" F	80	
			762 "

Section 3, Bermuda to St. Thomas:

Main cable,	type D	931	
Intermediate cable,	" E	15	
Shore end,	" F	20	
			966 "
Total			4,953

For the present it has, however, been decided to postpone the Bermuda and St. Thomas section until the two main sections are complete; however, as the types of cable in this section are precisely similar to that of Section II., Bermuda to New York, the same description will suffice.

In the existing Atlantic cables the insulating medium is that of the well-known and generally used material, gutta-percha. In the present instance, however, the Directors have decided to employ india-rubber in that form known as Hooper's Material, as the insulator for their cable. Hooper's core has of late years been largely adopted, as for instance, for the Persian Gulf cable, the various English cables belonging to the Great Northern Company, and more recently the China and Japan extensions; but really specific information as to its performance is still wanting. The success of the present cable, being the longest stretch of cable yet attempted, will prove of material moment in the great question of Gutta-Percha *versus* India-Rubber.

The core for Section I. is the same

throughout, the protection differing according to the requirements of the depth of water. The details of this section are as follows:

Conductor.—The conductor consists of a strand of seven tinned wires of annealed copper of the best quality and manufacture, and the resistance of a nautical mile will not exceed 4.3 ohms resistance at the standard temperature of 75 deg. F.; this represents a conductivity of 92½ per cent. of pure copper. The copper strand will weigh for this section 300 lbs. per knot.

Dielectric.—The conductor will be insulated with Hooper's material to the weight of 250 lbs. per knot. This may be briefly stated to be pure rubber next the wire, a separating medium, then coatings of vulcanized rubber, and finally a jacket—the whole process being peculiar, but representing finally a compact insulated core.

The insulated conductor, or core, is protected with a serving of india-rubber felt, and subsequently with a serving of jute yarn, in quantity according to the requirement of the various types of cable.

Main Cable, Type A.—The served core is sheathed with nine galvanized homogeneous iron wires of No. 13 gauge, each wire being enveloped in five strands of best Manilla or New Zealand yarn, steeped in Archangel tar; the cable thus sheathed is further protected by a lapping of yarn in a reverse direction.

Intermediate Cable, Type B.—The sheathing of this type consists of 10 B. B. galvanized iron wire, No. 5, B.W.G., the completed cable receiving three coatings of silicated asphalt compound, and two coatings of jute yarn, placed alternately, the servings of yarn being reverse.

Shore End, Type C.—The shore end consists of type A complete, protected with a serving of well tarred jute yarn, and sheathed with twelve strands of three wires of B.B. galvanized iron wires. The total weight of iron alone is for this type about 15 tons per knot.

In Section II. the conductor and insulator necessarily, from the decreased length of the section, differ in weight, the particulars being as follows:

Conductor.—A seven-strand tinned copper wire, weighing 107 lbs. per knot, and of the resistance of not greater than 12.056 ohms at 75 deg. F., giving a conductivity equal to about 92½ per cent. of pure copper.

Dielectric.—Of a similar character to the main section, but of the reduced weight of 170 lbs. per knot.

Serving.—The servings are similar to those in Section I., but of a quantity dependent on the size of the cable required.

Main Cable, Type D.—Sheathing of nine galvanized homogeneous iron wires, No. 13 gauge, protected with five strands of Manilla hemp, as in type A.

Intermediate, Type E.—Sheathing and hemp and asphalt compound, as in Type B.

Shore End, Type F.—This consists of Type D, served and protected in a similar manner to Type C.

The various types of cable have necessarily to pass through certain mechanical tests, and the "core" through electrical tests. The latter are as usual to be taken at the uniformly recognized standard temperature of 75 deg. F.; the required tests for the conductor have been mentioned, but the standard for the dielectric is high, unapproachable by gutta-percha. The dielectric resistance at this temperature is required to be not less than 3,500 megohms after *two* minutes electrification, and double that amount after five minutes. The inductive capacity—upon which so much depends—is in Section I. not greater than 0.43 microfarads, and in Section II. not less than 0.354 microfarads per knot.

Sufficient, however, has been said to show that a most satisfactory cable will be manufactured, and, whether as regards the insulating, conducting, or mechanical portion of the cable, the whole may be safely stated to be up to the contract point. Advantage has been taken of experience in one especial matter. The use of homogeneous iron in the Atlantic cable proved that there was a tendency in the iron when it became of a quality to much akin to steel, to fly, and damage the interior by penetrating the layer of cable above or below the broken point. Faults were undoubtedly caused by this evil; this, however, was sucessfully got over in the British Indian cable by a light "whipping" of yarn in the reverse direction to the lay of the wires; any breakage of the wire was consequently prevented from projecting by this method, and a similar plan had been adopted in this cable; so it is to be hoped the submergence of this cable will be as free from electrical fault due to that score as was the British Indian cable from Bombay to Aden.

PARAFFINE, ITS MANUFACTURE AND USES.

By PROF. CHARLES A. JOY.

From the "Journal of Applied Chemistry."

In 1830, Baron von Reichenbach, who died in 1869, discovered a white waxy substance in the products of the distillation of wood, to which, owing to its permanent character and chemically indifferent properties, he gave the name paraffine from *parum affinis*. Since that time it has been observed that it is produced during the distillation of many organic substances, such as resins, bituminous coal, lignite, brown coal, peat, fats, wax, bituminous shales, bog head coal, and that it occurs ready formed in petroleum, in the mineral ozokerite, in bitumen and earth wax. From being an article of insignificant chemical importance, it has risen to the front rank of valuable technical products. I distinctly recollect seeing in a small case at the Paris Exhibition of 1855 a few candles and a white block resembling spermaceti, on which was inscribed the word "*paraffine*." Not one in ten thousand of the passers-by had the remotest knowledge of what it was. In the Paris Exhibition of 1867 this article made its appearance everywhere, and I dare say there were tons of it in the building. The applications of paraffine are now so numerous and important that it is difficult to trace them through all of their ramifications, and I can only aspire to a very imperfect attempt in this direction. The best source for the literature on the subject is "Wagner's Annual Reports on Technology," and of that I shall make free use.

The methods for the manufacture of paraffine are different, according to whether it is a direct or an incidental product. I shall mention some of the most important processes actually pursued in the arts. That paraffine was contained in petroleum was known as early as 1820, and Buchner, who found it at that time in the Bavarian oil, is sometimes called its discoverer. The idea of employing petroleum as a source for paraffine was not fully cultivated until 1856, when the market became supplied with an oil unusually rich in this material. American petroleum contains very little, but the Indian, and especially Rangoon and Java oil affords from 10 to 40 per cent. The crude petroleum is distilled until 25 per cent. has gone over; the remaining portion is subjected to a higher temperature, and toward the last the paraffine goes over, which is condensed by surrounding the tanks with ice or artificial mixtures for the production of cold.

Latterly the manufacture from ozokerite has been conducted on an immense scale. The introduction of this name into commerce affords a striking illustration of successful advertising. It is said that the originators of the word spent £20,000 sterling in posting it on to every available dead wall, conspicuous rock, high fence, and in advertising it in every language and every country, until the curiosity of the whole world was raised to a high pitch in anticipation of the coming wonder. After waiting a number of years, public curiosity was gratified by the appearance on the market of some remarkably fine candles, which, on inspection, proved to be the well-known paraffine. The capital invested in the new enterprise is very large, and the production of pure paraffine something startling. Ozokerite, as it is found in Austria, Moldavia, the Caucasus, and near the Caspian Sea, is a vegetable wax of a yellowish color, fibrous structure, and light specific gravity. In its natural state it will melt readily, but requires to be wrapped around a wick before it will burn. About 300 lbs. of the crude material are subjected at the time to fractional distillation in an iron still, provided with coolers and condensers. The yield is 8 per cent. oil and 60 per cent. paraffine. The oil is reserved for illuminating purposes. A small portion of the light oil, which boils before 212 deg. Fahr., is subsequently used in refining the paraffine. The crude paraffine contains an oil which is removed under a hydraulic press, and distilled to save adhering paraffine, and for other purposes.

The press cakes are melted and treated with sulphuric acid. The acid is neutralized with lime, and the paraffine distilled off. The product is again pressed, melted with the light oil mentioned above, and once more pressed. The final result is a perfectly white, transparent, hard substance, quite pure and inodorous, having a metallic ring, and fusing at 63 deg. C. (113 deg., Fahr.). Its chief use is in the manufacture of candles. The bitumen from Trinidad, Cuba, Cali-

fornia, Nicaragua, Peru and Canada, is also proposed as a source for paraffine. That from Trinidad yields nearly 2 per cent. The manufacture of paraffine by the dry distillation of peat and bog head coal is divided into two operations: 1. The production of tar. 2. The working up of the tar for illuminating oil and paraffine. Before the discovery of petroleum, this industry was regarded as one of great importance, and it was anticipated that most of our burning oil would come from this source. The trade name of the oil was *kerosene*, a word which has since been applied to refined petroleum. After the introduction of petroleum, the bog head industry declined in the United States, but it is still important in Scotland, where great quantities of paraffine are yearly made, according to Mr. Young's patent. Mr. Young originally subjected the bog head coal to a downward distillation, but numerous modifications have been introduced according to the nature of the crude material. More attention has latterly been bestowed upon the coolers and condensers than formerly. The methods of compressed air, ether engines, and condensation of ammonia, have been applied to the cooling of paraffine on a large scale, and the yield has thus been appreciably increased.

It is in this method of artificial refrigeration that the chief progress has been latterly made. Paraffine, in its pure condition, is a white, waxy, inodorous, tasteless substance, harder than tallow, softer than wax, with a specific gravity of 0.877. Its melting point is variable, depending somewhat upon its origin. It ranges between 43 deg. C. and 65 deg. C. (109 deg. Fahr. and 151 deg. Fahr.). An ultimate analysis yields, on the average, carbon 85 per cent. and hydrogen 15 per cent. It is insoluble in water, and is indifferent to the most powerful acids, alkalies and chlorine, and can be distilled unchanged with strong oil of vitriol. Warm alcohol, ether, oil of turpentine, olive oil, benzole, chloroform and bisulphide of carbon dissolve it readily. It can be mixed in all proportions with wax, stearine, palmatine and resin. As stearine is less soluble in benzole than paraffine, Vogel proposes this reaction as a method for detecting the adulteration of paraffine with stearine. Further properties can be inferred from the uses to which it is applied. It burns with a wick, and gives much more light than stearine or wax, but as it melts at a low temperature, it cannot be advantageously employed alone. When required for candles, it is melted with stearine, wax and spermaceti, to render it less liable to bend over in warm weather, or to run. There are single establishments in Germany capable of turning out 250,000, candles daily, and in England even these figures are exceeded. As the melting point of paraffine is low, it is proposed to employ it for the preservation of meat. Meat several times immersed in a bath of melted paraffine will keep for a long time, and when wanted, it is only necessary to melt off the adhering wax-like coating to prepare it for cooking. For stoppers to acid bottles, to coat paper for photographic and other uses, as a lubricator, for candles, as burning oil, to coat pills, in the refinery of alcohol and spirits, paraffine now finds ready use. It has also been employed for the adulteration of chocolate and candles; for the preservation of railroad timber; to saturate filter paper for certain purposes; to coat the sides of vessels in which hydrofluoric acid is to be kept; to preserve fruit from decay; for oil baths of constant temperature; to prevent the oxidation of the protoxides; to render fabrics water-proof; as a substitute for wax in the manufacture of matches; as a disinfecting agent, and as a varnish for leather.

Franz Stolba, of Prague, suggests the use of paraffine as a coating to vessels of glass or porcelain when these are acted upon by certain liquids to be set aside for crystallization. The paraffine is put into the capsules, previously well dried and heated, till it commences to boil; the vessels are then turned about so as to bring the paraffine in contact with the whole of the interior surface, and then empty out the surplus. After cooling, it is found to hold well, and the vessels are ready for use. Of course the solutions to be crystallized must not be heated, but left to spontaneous vacuum evaporation.

Wine and beer casks are rendered tight by paraffine, and its introduction into the vacuum pans of the sugar industry is said to prevent frothing of the syrup. Plaster casts are coated with it; drawing paper is rendered transparent; parlor matches are tipped with it; sponges are kept elastic; cloth is rendered water-tight, and it is employed to keep shoemakers' wax soft and pliable. A paraffine insulator is in use upon some of our telegraph lines, and as there are few substances that can attack or

decompose paraffine, its value in many chemical processes is obvious. One of the most recent uses is in the manufacture of sulphuretted hydrogen gas. If sulphur and paraffine be boiled together in a flask, decomposition takes place, and a copious supply of sulphuretted hydrogen is given off. I have found this to be one of the most convenient methods for the preparation of this gas for class-room experiments. In medicine, the preservative and protective properties of paraffine are brought into frequent requisition, and in candles it also plays a part.

Such are some of the leading features in the manufacture and uses of paraffine.

THE PNEUMATIC DESPATCH.

From "Engineering."

It is nearly seven years since a pneumatic tube was first laid in the very heart of London, and its working proved to be perfectly successful. Notwithstanding this, the great public carriers—the railway companies—and the Post Office authorities, have not yet availed themselves of the manifest advantages offered by this system for the rapid transmission of small parcels and mail bags. Descriptions of the pneumatic tube and the apparatus for working it were given by the press in November, 1865—when the first section was opened. The details have been slightly altered in one or two instances. The pneumatic tube is formed in two sections with a station in Holborn. The first section—that between Euston and Holborn—is 3,080 yards in length, and is laid with easy gradients. The section between Holborn and the Post Office is 1,658 yards in length, and on it two gradients of 1 in 15 occur. The station at Holborn is placed at right angles to the direction of the tube, so that all through trains must reverse there. This is effected by allowing a train on its arrival to run from one tube up an incline, down which it quickly descends by gravity, and is turned on to the pair of rails leading to the other tube. This shunting is effected very rapidly, occupying only about half a minute. The tube is of the horseshoe section, the internal dimensions being 4 ft. 6 in. vertically, and 4 ft. horizontally. The carriers or trucks are 10 ft. 4 in. long, and the ends present an outline conforming to that of the interior of the tube, the edges of the ends being bound with an elastic medium, so as to form pistons when in the tube. The carriers weigh about 1 ton each.

The machinery by which the transit of the carriers is effected is placed in the rear of the Holborn station. It consists of an engine having a pair of 24 in. cylinders with 20 in. stroke. A fan 22 ft. in diameter is geared at 2 to 1 with the engine and is worked continuously, the alternate action of pressure and exhaustion being governed by valves. Steam is supplied by three boilers, each 30 ft. long and 6 ft. 6 in. in diameter. The ordinary working speed of the fan is 160 revolutions per min., which gives a pressure of about 6 oz. per sq. in. Trains are drawn by exhaustion from Euston-square and the Post Office, and are propelled by pressure to those points. The signalling between the stations, and the various operations connected with the opening and closing of the entrances to the tubes for the admission and emission of trains, are performed from a platform immediately over the mouths of the tubes. The doors of the tubes are arranged at Holborn and the Post Office on the principle of lock-gates, being hinged vertically and hung in pairs. Should an accident, however, happen to these gates, a considerable time would be consumed in replacing them. In order to avoid this possible delay, the pair of gates at Euston have been superseded by a single flap, hung with a horizontal hinge. By this arrangement, and by having a spare gate always at hand, the delay occasioned by an accident to a gate would only be of a few minutes' duration. The brake arrangement, in use at the Post Office and the Euston stations, consists of a pair of broad wooden rails, 20 ft. long, laid inside the ordinary iron rails, and having a slight incline. As the train on its arrival leaves the mouth of the tube, it runs on to the timber incline, the undersides of the carriers—which are shod with iron—sliding up the incline, and the wheels

being raised from the rails. To release the carriers for the return journey, the skid is lowered by a cam arrangement, which brings the wheels down on the rails again.

Such is, in general terms, the machinery of the Pneumatic Despatch, the working of which was lately illustrated to a number of scientific gentlemen and others. The trials commenced by bringing a single carrier, by exhaustion, from the Post Office, the run being accomplished in 3¼ min., a longer time than usual, accounted for by the carrier having been over-buffed, the pressure being relieved a little too soon. This carrier was then coupled to two others, and the three sent to Euston under pressure in 6¼ min. from the time of leaving Holborn. The train was next brought from Euston by exhaust, the time occupied being 5½ min. It was then run into the Post Office tube, and in 2¼ min. from the time of starting it had reached its destination. It was then sent on the return journey, which was accomplished in 3 min. as far as Holborn, and in 7 min. more it had arrived at Euston. The time here was exceptionally long, but the pressure was rather low. Finally the train was brought back from Euston in 5¼ min.

Experiments of such short duration as the foregoing, carried out, moreover, without any recent practice by the men in charge, can hardly be taken to represent the results of actual practical working. Some interesting facts, however, in connection with continuous working were established by Mr. W. H. Barlow, who in the early part of the present year instituted a series of careful experiments with the pneumatic tube, which lasted over several days, and showed the difference of power required to work the gradients of the Euston section of the tube as compared with the Post Office section. Before giving the results of these experiments it will be as well to notice the number of revolutions of the engine required to maintain given pressures in the tube. One feature proved by these experiments was, that whether the tube was closed at both ends, or closed at one end and a carrier inserted and fixed at the other, or whether a train was moving or not, and again whether each tube was put in connection with the fan separately, or both were put in connection with the fan at the same time, in all those cases there was—as might be expected—but little variation in the number of strokes required to maintain given pressures. The following results obtained by Mr. Barlow fully illustrate this point:

Condition of Tube.	Number of revolutions of engine.	Pressure in ounces.
Euston tube closed at both ends	79	4.0
Tube closed at one end and a carrier inserted at the other	80	3.8
With a train of 2 tons running in the Euston tube	81	4.0
With a train of 12 tons running in the same tube..... ...	79	4.0
With a carrier inserted in each tube and both tubes in connection with the engine....	80	3.3 rising afterwards to 4.0
Ditto ditto	92	5 35
The Euston tube separately....	92	5.80
The Post Office tube separately	92	5.20

The last result having an important bearing on the usefulness of the apparatus, Mr. Barlow made a set of experiments, and, taking the average results of the different pressures, it appears that the increase in the number of revolutions required to maintain the pressures in both tubes acting together, as compared with either acting separately, amounts to 5 per cent. It was observed, however, that when a regular speed was arrived at with both tubes in connection, the effect of shutting off one tube was, of course, to produce a slight increase of speed in the engine, the total amount of work done being diminished by the reduction of the quantity of air delivered by the fan. It was, however, evident that so much of the work performed by the engine was expended by overcoming the frictional resistances of the fan itself, that the difference between operating on one tube alone, or on both together, did not produce a large effect on the gross work demanded from the engine. A number of experiments were made with the dynamometer for the purpose of ascertaining the tractive resistance of the carriers. The results, however, were irregular, but the general mean is stated to be 25 lbs. per ton. This unusually high resistance was obtained under exhaustion, and is therefore referable to the small diameter of the wheels, and the generally imperfect construction of the carriers. With regard to the actual weights moved, and speeds obtained, numerous experiments made on the section between

Euston-square and Holborn give the following results :

Number of experiments from which mean result is obtained.	Gross weight carried in tons.	Times of transit through tube.	Speed per hour in miles.	Gross weight passed through the tube per minute.	Revolutions of the engine per minute.	Nominal pressure in ounces.
		m. s.		tons.		
6	2	7 20	14.32	27	81 5	4
6	2	6 33	16.03	.30	90.0	5
6	2	6 4	17.31	.33	93 0	5½
2	6	9 15	11.35	.65	71.5	3
2	6	8 15	12.66	.73	77.0	4
2	6	7 12½	14.26	.83	87.0	5
2	6	6 23	16.44	.94	95.0	5½
22	12	9 3	11 60	1.33	79.0	4
36	14	7 55	13.47	1.77	86 5	5
22	20	7 59	13 15	2.51	93 0	5½

The nominal pressures recorded in these experiments agree very closely with those obtained by the same number of revolutions of the engine when the tube was closed, and no train running in it. The remarkable feature of these experiments is that, with the same number of revolutions per minute of the engine, and the same pressure, a very large increase made in the load produced a comparatively small decrease in the speed. This is shown by the following nine experiments :

Nominal pressure.	Load conveyed in tons.	Speed, miles. per hour.	Number of revolutions of engine.
4	2	14 32	81 5
4	2	12 66	77.0
4	12	11.60	79 0
5	2	16 03	90.0
5	6	14.26	87.0
5	14	13 47	86 5
5½	2	17 31	93.0
5½	6	16.44	95.0
5½	20	13 15	93.0

In the first of these cases, by increasing the load from two to twelve tons, the useful effect, or weight passed through per minute, was increased five times. In the last experiment, by increasing the load from two to twenty tons, the useful effect was increased about seven and a half times; the pressure of steam and the work performed by the engine remained about the same, whether a weight of two tons was passing through at 17.3 miles per hour, or twenty tons at 13.15 miles per hour. The peculiarity of the pneumatic tube apparatus is that it is not well adapted for light loads at high speeds, but that it is capable of moving a great amount of weight at low speeds. The experiments made by Mr. Barlow upon the section of tube between Holborn and the Post Office showed that, notwithstanding the gradient of 1 in 15, the heaviest loads were those which produced the best commercial results, and that with twelve tons the weight passed through the tube was 2.66 tons per minute. The pressure required to work this action of the tube is greater than that required for the Euston section. Considering the imperfect condition of the rolling stock, there can be no doubt that the mean results obtained in these experiments could be readily obtained in ordinary every-day working with the road and rolling stock in efficient order. It appears from the experiments that twelve tons were taken through the Post Office tube in 4½ min., and twenty tons through the Euston tube in 8 minutes. Assuming the engine to work on each tube separately, two trains of 12 tons might be brought through the Post Office tube in 9 min., and might be sent forward to Euston in one train of 24 tons in about an equal time. In other words, 24 tons might be passed through the entire length of the tube in 18 min., or, allowing 6 min. delay in shunting, etc., at the stations, the practical result would be 1 ton of gross load per minute. By reducing the trains to 10 tons in the Post Office tube, and to 20 tons in the Euston, both tubes could be used simultaneously, and about 40 tons could be passed through in 18 min., or, allowing for delay at stations, from 1½ to 2 tons per min. of gross load.

The working expenses are estimated at £50 per week, working 12 hours per day, and the repairs at £500 per annum, an allowance which Mr. Barlow considers to be ample. He, moreover, observes that if sufficient traffic could be found to render it desirable, the carrying power of the apparatus could be greatly increased. For this purpose he suggests the employment of a powerful air-pump in connection with the Post Office section to assist the trains up the heavy gradients of 1 in 15.

THE new car shops at Litchfield, Ill., are fast approaching completion.

THE SEWAGE SYSTEMS.

From "The Architect."

At the present time there are so many different methods employed of treating sewage that it is often difficult to remember the difference between them, and a short abstract of the facts has been hitherto a desideratum. The nearest approach to such an abstract which we have met with, we must say, has been in a report presented to the Town Council of Beccles at their last meeting, and which appears to us to be so valuable a document that we reproduce it without abridgment:

At a meeting of the Council, a deputation, consisting of the Mayor (Mr. Laws), the Deputy-Mayor (Mr. Mayhew), Dr. Metcalf, and the Town Surveyor (Mr. Fenn), were appointed "to visit such sewerage works as they may think expedient for the purpose of obtaining information on the best method of disposing of the sewage of the town, and to report thereon."

In accordance with this resolution, the deputation visited the towns of Romford, Croydon, Leamington, Warwick, Banbury, and the works at Crossness, inspected the sewerage works and farms in connection with these places, and have endeavored to obtain such further information to assist them in forming a conclusion so as to recommend to the Council the adoption of a plan for the disposal and utilization of the sewage of the town of Beccles of a permanent and beneficial character.

Before presenting what must necessarily be a brief report of their visits to the places named, they would remind the Council of certain facts connected, first, with the nature of sewage; and, secondly, with its treatment and application, closely dependent as these are upon its character, and the special circumstances of the towns concerned.

The composition of sewage necessarily varies considerably in different places, dependent, for instance, upon whether it may be sewage pure and simple, or much altered in its character by the admixture of the refuse from manufactories and works, as is the case in many large towns.

The principal valuable constituents, however, are in all instances the various combinations of nitrogen, and the compounds formed with phosphoric acid.

In considering the subject, it is most important to bear in mind and discriminate between matters simply suspended in sewage, and those held in solution. Suspended matter, which may be separated in a variety of ways, either by precipitation or filtration, to those unacquainted with the subject might be considered to form the most valuable portion for manurial purposes; but this is erroneous, as the matters which are dissolved in the fluid portion are by far the most valuable for fertilizing purposes.

All the plans hitherto devised for the treatment of sewage may be considered under two heads, viz.: Artificial and Natural.

ARTIFICIAL PLANS.

The artificial plans adopted are either of a simple mechanical kind, or of a more complex chemical nature.

As examples of the mechanical treatment, we may mention the separation into solid and fluid portions, as we observed at Banbury, by means of screens and filters differently arranged, and again by the beautifully-constructed and ingeniously-contrived invention of Mr. Baldwin Latham, termed "an extractor," two of which are in operation at Croydon.

The chemical methods adopted have been both various and numerous, viz.:

1*st*.—The lime process, which was tried at Leamington and proved a failure.

2*d*.—Tanks, in which the sewage was treated with a preparation of alum, and was tried with partial success at Tottenham.

3*d*.—Lime and chloride of iron process, which is in use at Northampton. Each 1,000,000 gallons of sewage is mixed with 12 bushels of lime and 6 gallons of chloride of iron—in hot weather more, in cold less. The defecated sewage is then submitted to upward filtration through a stratum of calcined iron ore, 8 in. thick. It is stated that the deodorization is successful, but that the putrefaction of the effluent water, although deferred, ultimately takes place, and the river is fouled—indeed, an injunction has been obtained, and the discharge into the river is no longer permitted.

4*th*.—The crude sulphate of alumina process, which was used at Stroud with partial success; the effluent liquid, however,

contains more solid matter in suspension than the sewage before treatment.

An improved modification of this process has been quite lately introduced by the Phospho-Alumina Company. The plan has been adopted, we believe, by the Tottenham Local Board; and, experimentally, it is being tried on a larger scale at Barking.

5*th*.—The concession to utilize the sewage of Paris has been given to the "Peat Engineering and Filtration of London Company." The conditions are that the sewage shall be disposed of daily, so as to emit no foul smell in the vicinity of the works, and that the refuse water should run into the Seine clear and free from organic matter. The engineer is Mr. F. H. Danchell, C. E. Peat, which is abundant near Paris, is to be cut by machinery, dried and carbonized. This plan has been employed at the Stoke Workhouse, where the sewage of 650 persons (about 10,000 gallons of sewage per day) has been successfully filtered. The same company are engaged to filter the sewage of Bolton. The filtration can be arranged to take place upwards, downwards, or sideways, and can be easily reversed.

6*th*.—The A B C process—probably the most important and efficacious of the various chemical plans yet proposed, and whose principal works your Committee visited at Crossness. In the A B C process 10,000 grains of raw sewage require from 16 to 18 grains of the A B C ingredients, exclusive of water. The compound comprises from 2 to 3 grains of crude-sulphate of alumina, 3 grains of animal charcoal, 10 grains of clay, and 1 or 2 grains of blood—these are mixed with 82 or 84 grains of water, making a total of 100 grains, or 1 per cent. of 10,000 grains of raw sewage. The sulphate of alumina is obtained in a cheap way from clay.

7*th*.—The dry-earth system, although efficacious in deodorizing, is by no means so certain in its disinfecting properties, and the difficulties in procuring the quantity of earth required—the expense of bringing it to the houses, the removing it, the sifting and drying required, the care necessary to keep the earth dry, the incessant use of it in sufficient quantity but without excess, the fact that it would be chiefly used by the least careful class of the community, and its not dealing with other than fecal matters—render its success hopeless. The value of the manure produced, according to the Royal Agricultural Society, is only 7s. per ton.

8*th*.—The Midden plan, as adopted at Birmingham, is simply a temporary and imperfect device, to alleviate acknowledged and grave difficulties for which no remedy has been yet devised.

9*th*.—Filtration is effected by Mr. Weare's process through charcoal and cinders, in a specially constructed tank, as at Bradford, but with by no means satisfactory results. Charcoal has been similarly used at Uxbridge; the result, however, is so imperfect that an injunction has been obtained to stop the process.

NATURAL METHODS.

It now remains to consider what may be called the natural methods—these are "Downward intermittent filtration" and "Irrigation."

1*st*.—Downward intermittent filtration consists in adapting a small given area of land, over which the sewage is poured and caused to percolate through to a depth of several feet, more or less, dependent upon the nature of the soil, and carrying off the percolated fluid by means of regularly-constructed under-drains.

When this given area becomes non-absorbent or clogged, it is then allowed to rest, and a fresh portion of land is set apart, and similarly dealt with. Here very little attempt is made to cultivate a crop; the land is principally used as a purifier or filter. The sewage may be disposed of, it is but little utilized, and by far the largest proportion of its valuable properties are lost.

2*d*.—Irrigation has been carried on at the Craigentenny meadows, near Edinburgh, for the last 200 years. The lower portion of the present meadow, fifty years ago, was low moving sand-hills. The quantity of sewage there used is enormous—at the rate of 350 persons per acre.

One of the best examples of this method of dealing with sewage is to be seen, however, at Croydon, where for several years past there have been ample opportunities of observing and testing this system. Abundant experiments have been made from time to time, and the whole is now pretty well reduced to a systematic science.

The purifying agents in all cases of irrigation are twofold, viz.—the plant, which separates for its nutriment certain principles; and the soil, which abstracts the remaining

deleterious matter, storing it up for the use of future crops, thus rendering the effluent water clear, wholesome, and pure. The theory of sewage irrigation may be shortly stated, viz. :—That the sewage of a town may be so applied to land, that the rootlets of the growing crops shall at once seize upon the mischievous elements in the sewage, change their chemical forms, fix a portion of the elements in the plant, and render the rest comparatively harmless. This change is best effected before decomposition shall have advanced far enough for the dangerous elements to escape into the atmosphere, and so carry with them the germs of disease. If the application to the land be properly managed, the whole of the material supplied will be rendered innocuous, and the water freed perfectly from noxious organic matter.

The first great point in the management of irrigation is to establish a proper vegetable growth ; the second is to be careful that the debris of animal life shall not be in excess of the decomposing or fixing power of the vegetable.

The same points have to be observed in the proper and healthy management of an aquarium. In the aquarium, if the animal life overpower the vegetable growth, and also if the animal life does not remove the vegetable growth, both are destroyed. The same results will be obtained from the improper management of a sewage farm.

If the sewage is irregularly or unequally distributed, if it is in excess of the growing power of the crop to alter and assimilate it, the proper plants are killed and dangerous miasmas arise.

A sewage farm, however, is safer than an aquarium, because the land possesses certain properties which water has not.

The earth can hold a portion of the fertilizing elements contained in sewage, and store them up against the time when the plant is ready to appropriate them to its own use. This is a property possessed by some soils more than others—argillaceous soils in excess of sandy soils.

It is not the deodorizing or re-arranging powers of earth, however, which are required so much as the selecting power of the plant roots. Experience of some years has now shown that one acre of land will amply provide for the sewage of 100 persons.

The storm, surface, and subsoil waters should be separated from the sewage.

Sewers free from deposit and well laid are absolutely necessary for success.

The great value of sewage is in its fresh application ; the great danger, in its delay. It should reach the roots of the plant a few hours at most after its discharge from the outlet. And lastly, the necessity for proper under-drainage of the irrigated land must be carefully attended to (the nature and character of the soil being taken into consideration). It is not sufficient to pour sewage upon the surface of the land, making no provision for carrying off the fluid portion, as this would be simply to convert it into a stagnant pestiferous bog, inimical alike to animal and vegetable life ; but attention to the principles already enunciated will convert a barren sandy waste into a fertile soil bearing verdant and luxuriant crops, alike pleasant to behold, and beneficial in the varying supply needed for the wants of man.

Having thus given a brief account of the various methods adopted for the utilization of sewage, your Committee proceed to describe such as are in use in the several places they visited, with a view to ascertain how far any such application might be suited to our own case, and to the local conditions affecting our own drainage scheme. Your Committee selected such places as were understood to have some relation to our own locality—either in the size of the town, character of the adjoining land, or as cultivating by different methods of irrigation such crops as would be most suitable and marketable here.

These places were Romford, Croydon, Leamington, Warwick, and Banbury. With a wish, however, to get the latest and most reliable information as to the treatment of sewage by the A B C process, they inspected also the works at Crossness.

THE ROMFORD SYSTEM.

Your Committee first went to Romford. The sewage here is brought from the town —a distance of three miles—by an 18-inch iron pipe to the collecting tanks. The size of each tank is 100 ft. by 75 ft. by 8 ft. in depth, and the capacity of each is 350,000 gallons. Received at the tanks the sewage is allowed to settle, and the fluid part is pumped so as to command the highest point on the farm, and then conducted, partly by iron and partly by Portland cement carriers, over the land. The deposit left in the tanks

is afterwards raised and carted away for use as manure.

The result of the application of the fluid part of the sewage by irrigation appears to answer well. Crops are grown of strawberries, cabbages, onions, peas, beans, mangel-wurtzel, and largely of Italian rye-grass. Of the latter growth, as many as ten cuttings have been made in the year. On account of the proximity of Romford to the metropolis, garden produce is in demand, and sells well. Cabbages have been sold for £22 10s. per acre, and strawberries have realized £100 per acre. The sewage deposit (no means being used to fix the ammonia) is considered to be worth no more than its carriage; and its exposure (as permitted here), if near a town, would be an intolerable nuisance.

Of the object sought to be gained here—the utilizing the fluid part of the sewage by irrigation and the solid part as manure—the first is a great success, and the latter is as great a failure.

THE CROYDON SYSTEM.

The sewage of Croydon finds its way to the Beddington Farm by gravitation, flowing with sufficient force into a reservoir to set in motion a turbine which turns two circular screens of coarser and finer gauge, through which the sewage passing the solid matter is intercepted, and raised by an archimedian screw to an upper platform, to be barrowed away to a heap. The strained liquid is conveyed by underground mains to hydrants, and, being turned into stoneware carriers, is distributed over the land. The effluent water flows off very clear into the river Wandle. The machinery employed is expensive, but, on the other hand, there is no permanent cost for steam power.

Farm and garden crops grow here, and are looking well. There are about 160 acres of rye-grass, and 70 acres of permanent pasture. The manager reports that irrigation is highly beneficial to grass lands, improving the crops both in quality and quantity, and states that cattle much prefer the feed so grown.

A dairy farm with about 50 cows is carried on; the milk is excellent, and the cream and butter command top prices in the market. About 50 horses are taken in to keep, and are said to do well.

The land is well under-drained; indeed, the drainage of all irrigated lands is absolutely necessary. Nothing being paid for sewage, the farm, now in the hands of a company, makes a good profit. At the last balance 30 per cent. on the capital was made, of which 15 per cent. was taken by the shareholders.

THE LEAMINGTON SYSTEM.

The Leamington sewage is taken on lease by the Earl of Warwick at a rental of £450 per year. It is pumped by the Leamington authorities to the highest part of the Earl's farm, 2½ miles off, to the height of 130 ft., and from thence distributed in the usual way over the land. There is no separation of the solid from the liquid sewage; it is applied as it comes to hand, and its effects are unmistakable.

Italian rye-grass is grown in immense quantities; the first three or four cuttings average 15 tons per acre. It sells for 12s. per ton on the spot. Here, as at Croydon, cattle prefer pasture which has received sewage. Cows are in splendid condition, and yield nearly double quantity of milk of a superior quality. Horses also thrive well on the same produce. The farm, which is 360 acres in extent, of loam and gravel soil, under the management of the Earl's agent (Mr. Tough), is in the highest state of cultivation. Besides rye-grass, root crops are successfully grown. Mr. Tough, who furnished readily all the information your Committee required, is very strongly in favor of irrigation, but says it requires judgment and experience to apply it properly.

The money results of the farm, although so much is paid for the sewage, are likely to be satisfactory.

THE WARWICK SYSTEM.

The farm at Warwick is treated in a similar manner. The manager contends that clarified sewage is far better than sewage in its crude condition for grass lands, and says that the effect of its application to permanent pasture is to give three certain crops instead of one. Here garden crops pay best, and preparation is being made for growing them extensively. Celery, onions, and cabbages are to be principally cultivated.

An illustration was here seen of what might be useful to Beccles—there being a large breadth of permanent pasture under cultivation, and a good deal of hay is made. Here, also, was observed a stack of hay made from Italian rye-grass, which seemed sweet and clean, and which the cattle eat readily.

This farm at first was a decided failure. The land is heavy, and was not at first under-drained; and the result was that it became water-logged—receiving harm rather than help from the sewage. It is now managed with more judgment, and promises well.

THE BANBURY SYSTEM.

At Banbury, the sewage is received into tanks, situate near the town, and, passing from one tank to another, a simple contrivance separates the solid and floating substances from the liquid sewage, and this flows to the pump. The bottoms of the tanks are inclined to facilitate the collection of the deposit, which is raised in buckets, and being mixed with the town sweepings is sold at elevenpence per ton as manure; about 100 tons per annum are sold. The pumping main runs up the public road to the farm, the highest lift being 21 ft.

The sewage received into the main carrier is from thence distributed, the effluent water running into the river Charwell. An 18-horse pumping engine is employed, which raises about 400,000 gallons a day. The sewage is applied to permanent pasture during the winter, but never while the grass is growing.

No stock is kept, the produce being sold. The farm consists of 136 acres. The capital invested is £5,000. The result, after the payment of working expenses (nothing being allowed for sewage), is about an even balance.

It should, however, be remarked that the land, formerly letting for 50s. per acre, was bought at so high a figure as to raise the estimated rent to £4 10s. per acre.

The drainage of the town is all but complete—every house, with the exception of about thirty, being in connection with the sewers.

It is worthy of notice, that notwithstanding the perfect collection of the sewage and its being turned to good account, nothing more can be said than that it simply pays the expense of riddance.

Besides the foregoing places which appeared to afford more or less instructive examples to Beccles, your Committee thought it desirable to visit the great outlet of the South London sewage, and the works of the company manufacturing native guano by the A B C process at Crossness.

SYSTEM AT CROSSNESS.

It is unnecessary to refer to the Metropolitan works further than to say that in their gigantic dimensions, and with their enormous power, they seemed well worthy to deal with half the sewage of the most populous city in the world. With regard to the A B C manufactory, the works are placed provisionally on lands belonging to the Metropolitan Board, the company having simply permission to occupy them for twelve months. Should the works prove a nuisance, they may be stopped at once. They erect their buildings, machinery, etc., at their own cost, while the whole of their operations are under the surveillance of the Metropolitan Board.

On the part of the company, it is an experiment—on the part of the Board, an official inquiry. The daily quantity of sewage discharged at Crossness amounts to no less than 50,000,000 gallons, or 223,000 tons. Of this, about 600,000 gallons only is conveyed daily to the A B C works. It flows through a large pipe, and is pumped up into a cylindrical tank placed upright in the mixing room. It enters in at the base of the tank, and has a junction at this point with a pipe which conveys the A B C mixture, so that the sewage and the mixture are mingled together at the moment they enter the tank. The quantity of the A B C mixture or compound added to the sewage is about 1 per cent. The commingled fluid then flows into a series of outdoor tanks. Each tank when full is allowed to remain some hours, when the floor of the tank becomes covered with a thick deposit, while above is clear water, which is run off by means of pipes and valves into an open channel a little below the level of the tank floors, and finally enters the Thames by an aperture in the river wall in a bright pellucid stream. The mud deposit is next swept into the acidifying tanks, six in number, and is treated with dilute sulphuric acid to fix its ammonia—one part of the acid being used to a ton of the deposit. The final step is to dry this mud deposit. When dry, it is roughly pulverized and placed in bags, for sale as "native guano."

The price at the works is £3 10s. per ton, yielding, it is said, a profit of 30s. per ton. The works are a model of neatness, and the enterprise is considered to be successful, and is likely to be very largely extended.

The inquiry of your Committee here terminated. In this report they do no more than present to the Council such facts as

are of leading importance, and may be most easily understood and appreciated.

But, besides these, much valuable information has been collected, which hereafter must be of considerable service in the carrying out of any scheme for the treatment of land by the town sewage.

They may remark that much of this information could only have been gained on the spot, a fact apparently well understood by other corporations that have set on foot similar inquiries.

Your Committee have been fortunate in ascertaining what best to *do* in connection with sewage application, but perhaps yet more fortunate in ascertaining what it will be best not to attempt.

They cannot be sure that the first class of information will bring money to the corporate funds, but they are sure that the second will prevent what else might have taken place—its needless expenditure.

PLAN RECOMMENDED FOR BECCLES.

It only remains for your Committee, as the result of their inquiry, to indicate the plan which they think the Council should follow in the treatment and use of the town sewage.

Provision being made for the collection of the sewage to one point, special care having been taken to separate the surface and storm waters, they recommend that a tank or tanks be constructed capable, for some years to come, of containing one day's supply.

That suitable machinery be erected for pumping the sewage to the required height (from 20 to 25 ft.). That the land being previously laid out in proper form, the sewage should be conveyed to, and distributed over it by means of carriers; the fluid part of the sewage being thus disposed of, they recommend that the deposit remaining in the tanks be treated with dilute sulphuric acid (a very inexpensive process), then taken out and mixed with the contents of dust-bins, street sweepings, etc., so making a valuable manure. In recommending this as the best method, and perhaps the only one applicable to Beccles, they have taken into account what for some time must be the nature and amount of its sewage.

For the most part liquid, and very limited in quantity, it would be absurd to suggest anything more than the simplest and most inexpensive appliances for its reception and distribution, so that these are but sufficient. It would be equally absurd, remembering what must be the character of the sewage, to suggest any other means of application than by irrigation.

They have also taken into account, as compared with the sewage farms they have inspected, the position and nature of that part of the fen which can alone be subjected to sewage treatment.

They believe that by the means suggested not only will our permanent pasture be improved, but that the land will be found capable of growing successfully rye-grass, cereals, root crops, and garden produce. Much of this may be accomplished as soon as the sewers are partially brought into operation; but when completed, and a general connection of the houses of the town is secured, they have no doubt a return will be made proportionately equal to that of any town in the kingdom. This appears to be probable; but they would remind the Council (although it forms no part of their special duty to do so), that, after all, the supreme consideration in connection with the drainage of Beccles is the health of its inhabitants. Were it possible that any method in the treatment or application of sewage would result, not in a gain but a loss to the town, who would not deem any improvement in the condition of health and life infinitely more than an equivalent? *Salus populi suprema lex.* Some towns will find the riddance of their sewage to be a perpetual expense, some will be happily able to make it clear its own expenses; and some, much to be envied, will be able to bring good out of evil, and make it yield a positive profit; but in all, the great point gained, and that which throws all other considerations into the shade, is that the towns are purified, and the true conditions of health established. So with Beccles, whatever may be the money results of the use of its sewage—although your Committee have no fear on that head—its most important gain is removed far beyond the province of doubt, and that gain is no less than the certain diminution of disease and the extension of human life.

FROM the mines of Gilpine county, Colorado, nearly 600 tons of ore are raised daily. There are 83 stamp mills, 185 engines in place; 4,367 horse power, and 1,597 stamps. The deepest shaft sunk is 800 ft.

THE ARTIFICIAL DESICCATION OF WOOD FOR FUEL AND ENGINEERING PURPOSES.*

From "The Builder."

The methods hitherto employed to preserve the soundness of timber may be classed under one or another of the following heads:—

1. Applications to the surface of the wood, to prevent contact with the air.

2. Open-air immersion in some antiseptic liquid.

3. A process of suction or filtration, of which Boucherie's method is a type.

4. Injection with an antiseptic fluid with the aid of successive processes of exhaustion and atmospheric pressure.

5. Artificial desiccation in closed vessels, as a preliminary to some one of the above processes.

Several of the above-mentioned processes have formed the subject of valuable memoirs from the pen of the late M. Payen, in various scientific journals. In this paper his observations are designed chiefly "to illustrate the advantages of stove-action, both in the simple desiccation of wood and in preparing it for the aforesaid treatment." Some preliminary remarks are made upon the advantages attendant on the uses of thoroughly-dried fuel in metallurgical operations and other industrial processes:—

The presence of air and moisture in the pores of wood is one of the most active promoters of fermentative action in the organic tissues, and of the consequent changes which involve the ultimate destruction of the wood. These changes frequently carry off a notable proportion of heat producing substances; in like manner, the water contained in the wood, in the process of evaporation, absorbs and carries off a portion of the heat generated by the combustion of the surrounding ligneous matter, the heating power of which is reduced accordingly. To obtain a clear idea of the advantages secured by drying wood intended for use as fuel, we must compare the volume of heat generated by the combustion of a given weight of dry wood with that obtained from an equal weight of the same wood when wet or full of sap. The comparison may readily be made by taking the ordinary chemical composition of oak-wood as a standard, and comparing the equivalent amounts of carbon which it represents in each state. Now, 100 parts of dry oak-wood contain 50 parts of carbon, 6.20 hydrogen, and 43.80 oxygen. The heating power represented by the carbon must be augmented by the equivalent of the excess of hydrogen over and above that required to convert the oxygen present into water. In oak, this excess of hydrogen is about 0.630, which would be equivalent in heating power to 1.89 of carbon. The heating power of 100 parts of dry oak is therefore equal to 50+1.89, or, 51.89 parts of carbon, *i.e.* of pure charcoal. But to determine the amount of useful heat, we must reduce the above amount by the volume of heat absorbed by the hydrogen and oxygen which pass off in combination in the form of water. The water thus formed amounts to nearly 50 per cent. of the component elements of the wood, and the heat absorbed by it in the process of evaporation, at the temperature of combustion, is equivalent to five parts of carbon. Consequently, the amount of *useful* heat generated by the combustion of 100 parts by weight of dry oak-wood is equal to 50+1.89−5=46.87, or very nearly that of 47 like parts of pure charcoal.

We can easily compare the useful heat obtainable from 100 parts of wet wood, by assuming that oak-wood in this state will hold 45 per cent. of water; 100 parts by weight will thus consist of .45 of water and .55 of dry substances. As 100 parts of dry oak-wood are equivalent to 46.89 of carbon, 55 such parts will equal 25.79 of carbon. From this must be deducted the heat absorbed in the evaporation of the 45 parts of water, which will equal 4.50 parts of carbon. The useful heat obtainable from 100 parts of wet oak will therefore equal 25.79−4.50, or 21.29 parts of pure charcoal only. In other words, to generate a volume of heat equal to that supplied by 100 parts by weight of dry oak-wood, we require 225 parts of the same wood when it contains the proportion of moisture we have supposed above.

In addition to the loss thus occasioned directly, which in itself is serious enough,

* From the French of the late M. Payen, Member of the Institute,—"Annales du Conservatoire des Arts et Métiers," vol. x. 1871.

there are certain operations—such as glass-founding, the fusing and volatilization of zinc, and the like—in which it would be impossible to secure the desired results with damp fuel; the heat developed would only balance the loss caused by draughts and radiation. Thus, it will be seen that the desiccation of fuel—always of essential service—is, in certain metallurgical processes, absolutely a *necessity*. The preliminary drying can be most advantageously performed when it is possible to effect it with the waste heat carried away by the gaseous products of combustion. In cases where the wood is to be injected under atmospheric pressure, the previous elimination of the moisture contained by it will be useful in many ways, and is, indeed, essential to the penetration of heavy antiseptic preparations, such as *creosote*, sulphate of copper, and the like.

Two methods are available for this purpose:—

1. Natural desiccation, by exposing the wood for a lengthened period to the air, sheltering it, of course, from rain.

2. Artificial desiccation, in stoves of various descriptions.

Again, it is obvious that the impregnation of the wood with antiseptic fluids, in closed vessels, can only be effectually performed when the wood is in a sufficiently dry state to admit of the exhaustion of the air from its pores, and the entrance therein of the injection. If damp or newly-cut wood be subjected to the injecting process, the fluids contained in the tissues being confined on all sides, and virtually incompressible, cannot give place to the antiseptic liquid whatever may be the pressure exerted. Practically, therefore, injection in closed vessels is only feasible when the wood is sufficiently dry to admit of the exhaustion of the air or gases contained in its tissue and their replacement by the antiseptic fluid supplied by the pumps. This fact was recognized long ago. Hence the great number and variety of apparatus designed for the purpose. But in spite of the advantages which might fairly be expected to result from their employment, the latter have been very long in coming into general use; a fact which may, no doubt, be explained by their high price and imperfect construction, and the tediousness and costliness of the processes. It is only within the last few years past that the artificial desiccation of wood before its impregnation with an antiseptic preparation in closed vessels has been generally adopted in practice. Previously, it was customary to leave the wood—railway sleepers more especially—exposed to the air for a period of eight to twelve months, according to the season. This was very objectionable, not only on account of the loss of interest on the capital represented by the wood during this tedious process, but also by reason of the injury caused to the wood by atmospheric influences, the necessity for large and costly timber yards, and the concomitant expenditure in labor and transport, which were often ruinously great.

The first essays in the art of drying wood artificially carry us back to a period now tolerably remote. Wollaston and Fourcroy both recommended the drying of wood in ovens. Newmann, a German chemist, suggested another method, which has since been adopted in a somewhat different form, *i.e.*, *steaming* the wood. Newmann placed the wood to be dried in a large wooden chest, taking care to leave spaces between the pieces, and then turned on the steam from a boiler provided for the purpose. The condensed steam, charged with albuminous matter taken up from the wood, or rather from its surface, was run off from time to time, and the progress of the operation was judged by the color of the water. When the latter was clear and colorless, the chest was opened, and the wood withdrawn for use, without further preparation. The process would have been useful enough if *superheated* steam, which would have dried the wood by absorbing the moisture, could have been used, but the cost of the process would doubtless have been too high to permit of its practical application.

In 1837, M. de Mecquenem devised a method of desiccation in which the pieces of wood to be dried were placed in a closed chamber, and subjected to a current of hot air, heated for the purpose by a special apparatus, and driven by a blower. The air entered by apertures in the lower part of the chambers, and escaped at the top, laden wite the moisture absorbed from the wood.

In 1839, M. Charpentier obtained a *brévet d'invention* for a process of drying wood in hermetically-closed chambers. The wood was subjected to the action of air heated by contact with metal plates covering the flue of a coke furnace. This air entered by conduits on the level of the floor

of the chamber, and escaped at the top, through apertures leading into the chimney of the furnace. Between 1848 and 1853, Bethell, who had paid much attention to the subject, obtained several patents, both in England and France, for stoves for drying wood. In his English patent of 1848, and the subsequent French one of 1853, we find a description of a peculiar kind of stove on the following plan:—

It consisted of a rectangular chamber formed of three walls, and vaulted over; the whole in brickwork, with a certain thickness of slag in the centre, to prevent loss of heat. One extremity of the chamber was open, to admit of the introduction of the wood by means of a truck running upon longitudinal iron rails. The opening was closed with a double door when the chamber was full. On the exterior of the opposite end of the chamber was a furnace to burn coal, coke, wood, or tar, according as it was desired to *dry* the wood simply, or in the words of the inventor, to *smoke* it, *i.e.*, to impregnate it with the antiseptic gaseous matters evolved in the imperfect combustion of certain tarry substances. The heated air or smoke entered through a flue running along the floor and branching at the end; and it escaped, or was pumped out at the top of the vaults. Bethell considered that the interior of the chamber should be kept at a temperature of 110 Fahr., and that the duration of the process should be regulated by the condition of the wood. His experiments showed that this time varied from 8 to 12 hours,—the rapidity being attained at the cost of a relatively large expenditure of fuel. In point of fact, the draught was too great to permit of the utilization of the full amount of heat contained in the gaseous matter, which escaped at a temperature very little below that at which it entered. The heat produced by the fuel was badly utilized, and it is open to question whether, under any circumstances, large pieces of wood, such as sleepers, could be dried in so short a time as 8 or 12 hours. The drying could only be effected by the use of a very high degree of temperature, tending to split the wood and weaken its strength. This view was confirmed by the results obtained in a long series of experiments made in 1852–3 by an English manufacturing company, known as the Desiccating Company. A low temperature, and long continuance of the drying process, appear to be the conditions essential to the success of artificial desiccation, particularly with wood intended for cabinet-making, turning, joinery, ornamental work, etc., in which it is desirable, as far as possible, to prevent splitting, warping, and other changes of structure in the material. These results, it would seem, were not secured by the arrangements above described.

PERMANENT AND TEMPORARY STRUCTURES.

Written for Van Nostrand's Magazine.

It is not surprising that in this country, where, hitherto at least, all engineering works have been of necessity carried forward by an ingenious adaptation of whatever material may have been found at hand, rather than by a careful selection of that best suited to the required purpose; where the engineer has been constantly obliged, like Franklin's chemist, to "saw with a file and file with a saw," that the mere substitution of a comparatively indestructible material like iron for wood, should popularly be supposed to constitute the difference between a "permanent" and "temporary" structure.

Under the conviction that this hasty classification may lead to dangerous results, it is proposed in the present article to briefly review the practical aspect of the question in so far as it is connected with bridge-building.

Strictly speaking, of course there is no such thing as absolute permanency; but practically, we would define a permanent structure to be capable of lasting, with few or no repairs, as long as the use for which it was designed shall exist. When we examine the precedents afforded in the works of the ancients, we see that though absolute permanency may be unattainable, an unnecessary degree of it may easily be obtained. We see in all countries where Roman arms introduced Roman civilization, public works, as viaducts, aqueducts, and the like, standing as strong and staunch as when first reared by the hands of their indomitable builders, though the uses for which they were constructed have long since

passed away. They are instances of redundant strength, produced by a lavish use of the best material, and they would have equally well fulfilled their purpose had they been so built as to have crumbled to the dust ages ago. They have, in fact, long outlived their usefulness.

On the other hand, while we have all around us examples of railway superstructure carried over streams on rapidly rotting piling, requiring constant renewal, or at best on unpainted and unprotected timber bridges, we have not far to go for instances of the opposite extreme.

A truly permanent structure requires not only the use of an imperishable material, but of a sufficient quantity of it. It is not enough to calculate the strain on each member of a truss, and proportion each to such strain, allowing perhaps a margin of five times the breaking strain to constitute a permanent structure. A structure composed of elastic materials, as wood or iron, is constantly in play, no matter what precautions may be taken to stiffen it, and is consequently constantly wearing out, exactly as a man's coat is. If a structure, such as a bridge truss, is designed to be a permanent one, this wear must be provided for. We have no hesitation in declaring that, viewed in regard to wear, there are but few iron truss bridges in the country that have any claim to the title of permanent structures. Moreover, were it not that a croaking engineer is almost as distressing a spectacle as a crowing hen, we would not hesitate to predict a frightful series of disasters, owing to the sudden failure of many trusses to meet the calls upon their resisting properties—properties which sooner or later must be "taken out" of them by the ceaseless wear upon their members. We need not remind any engineer of the peculiar vice of iron as a material for construction, namely, its treachery. An iron tie or brace, on the very eve of rupture, gives positively no evidence of weakness to the most practised eye. Any one who has seen a wire rope part like rotten tow under less than its customary load, immediately after a careful inspection, knows how much appearances are to be trusted in iron work. We never approach the subject of the comparative quantities of different materials and modes of construction, without being forcibly struck with its analogy to human physiology. A deep, light, spider-like truss, each member containing the minimum of material, and the whole set up so stiff and taut with the counterbraces that it sings like a harp in the wind, is in perfect analogy with the man of high-strung nervous temperament, who, without a pound of superfluous flesh or muscle in his frame, is constantly driven on by the goading of his nervous system to the full extent of all his powers of endurance. In both cases there is no provision for wear and tear, and in both the final result is apt to be sudden collapse, when the over-worked members, completely worn out, "strike work" without warning. Both are very well in their way, but neither can be counted on for continuous and trustworthy effort.

If a bridge is to be constructed with a view to safety and permanence, it must fulfil one of two conditions. Either the material of which it is composed must be such as to plainly indicate symptoms of any approaching weakness, or else its members must possess immense redundant strength to afford abundant margin for wear and tear, and mechanical and chemical change in the nature of the material. The best material for permanent work is undoubtedly brick, or some kinds of choice stone; for it is not subject to wear, owing to its non-elasticity, and besides would indicate by cracking any failure of resisting properties. Timber, by betraying unmistakably any approaching weakness, is a perfectly safe material; and though we hear constantly of the failure of wooden structures, it is only because the warnings which they gave of impending rupture were unheeded. Iron, on the contrary, gives no warning, and betrays no weakness by which one might be prepared for the danger which menaces. The only safety in an iron bridge is, therefore, to proportion its parts to a strain vastly in excess of any that can possibly come upon it, and this for two reasons: first, for the actual strength, and secondly, for the additional weight, which secures a greater preponderance of the fixed over the rolling load. An iron bridge to be secure must possess sufficient substance to absorb the shock of the rolling strain. The universal *thrill* which runs through a light, taut truss, is very ominous of a brief existence.

We do not in the least wish to be understood as recommending a promiscuous piling on of material, merely to increase the weight of a bridge. On the contrary, the problem of the strains should be worked out with the greatest nicety, quite as much

so as if not a superfluous pound of material beyond the most strictly necessary amount were to be put in; but having thus found the position and magnitude of each strain, it should be provided for by an immense excess of material if the structure is intended to answer to the requirements of a permanant one. Moreover, the truss should in all cases be well counterbraced, not as a *remedy* for the shakiness of a too slight structure, but as a *preventive* against its appearance.

It may savor of old fogyism, but we cannot withold the assertion that the only true form for a *permanent* iron bridge is the plate, or tubular girder. It is undoubtedly the least economical form, as requiring the most material for a given resistance, but it is the safest and most *staying*; and if ever iron gives warning of impending failure, it is when in the form of riveted plates. On the other hand, the combination which requires the least material for a given strength, namely, the Warren system, aggravates in a singular degree all the worst defects of iron as a material for construction.

Iron, as a building material, is still on its trial; what little we know of its conduct under stress points to the fact that it cannot be depended upon to resist strains at all approaching its final limit. The question of how far permanency should be sought at increased first cost, is one that can only be answered for each particular case in which it may arise. But there should be no misapprehension as to what is a permanent and what a temporary structure.

INDIAN NARROW GAUGE RAILWAYS.

From "The Engineer."

The results of the labors of the commissioners appointed by Government to inquire into the working capabilities of the narrow gauge, and its applicability to the requirements of our Indian empire, are now apparent. A contract has been entered into for the construction of a line with a gauge of 3 ft. 3½ in., which will ultimately constitute a portion of the through communication from Bombay to the North-Western Provinces. The proposed line connects Kundwah, a station on the Great India Peninsula Railway, with Indoor, a city lying on the northern side of the river Nerbudda, about 70 miles distant. This, however, will be but the first link in the chain uniting Kundwah with Agra, a principal station on the East Indian line, connecting Calcutta with Delhi. At present there is a junction at Jubbulpoor of the Great Indian Peninsula and East Indian Railways, so that the route from Bombay is unbroken to both Calcutta and Delhi. The new line will not affect the through traffic from Bombay and all places south-west of Kundwah to Calcutta, but it will very seriously affect the traffic from the same places passing to Agra and Delhi and all the towns on the East Indian Railway north of the junction. The distance from Kundwah to Agra by the existing route is nearly 800 miles, but when the more direct one is established it will be about 430 miles, thus being reduced nearly one-half. It is an open question whether the main route from Bombay to Calcutta should not have been laid out more to the south and more direct than it has been; but many years must elapse before it will be possible to decide whether the principal railways in India have been laid out on a better plan than that which has characterized those at home. It must in fairness be kept in view that there are certain conditions attending the former which do not obtain in the latter. In a dependency, the allegiance of which to the ruling country must be maintained by the sword, reasons of a purely military character must have considerable influence upon the selection and determination of all main routes of intercommunication, whether they take the form of navigable canals, railways, or ordinary roads. The simplest method of arresting sedition and rebellion is to possess the power of rapidly concentrating a large military force upon any particular locality.

Many persons will be inclined to think that the Indian authorities, having in one sense committed themselves to a gauge of certain dimensions, ought not to change it. It is not of any practical use now to consider whether that gauge should ever have been adopted; but even supposing that its capabilities are not far in excess of any duty that can possibly be demanded of them, there is not the slightest reason that all

future lines, feeders, or others, should be constructed on a similar scale. Though it is true that the main lines are of too broad a guage, they form, comparatively speaking, but a mere tittle of the railways that must eventually cover the map of India, so that the authorities are as yet but very partially committed to any particular width of track. While it can hardly be asserted that railways of a gauge of 5 ft. 6 in. are absolutely necessary to meet the exigencies of Indian traffic, or the contingencies of military operations, yet bearing in mind what great interests might be at stake when rapid and abundant means of transport might be required, the error, so far as it has gone, has been on the right side. That the cities of Calcutta, Bombay, Madras, Delhi, and other important commercial and strategical *foci*, should be connected by a system of communication affording large facilities for the transport of men and material, will be universally admitted. Can this be adequately accomplished upon a gauge of 3½ ft? By judicious and skilful management, and in the hands of an able and experienced traffic-manager, a great amount of work could be got out of a line on the small gauge mentioned; but still there are limits to its resources. Our views are that a few, a very few comparatively, main routes should be laid out with great care and discrimination, so as to embrace the principal cities of a country such as India, and no others. These may be of a larger gauge than the secondary or subsidiary routes, which would act in the double capacity of forming links of intercommunication between towns of inferior importance, and at the same time become valuable feeders to the main arteries. If all the lines in a country are constructed upon the same gauge, it is equivalent to making all the roads turnpike roads. There are generally three kinds of roads—the turnpike, the public, and the occupation or farm road. No farmer would think of constructing his occupation, or private road, of the same dimensions as the highway, any more than he would use a four-wheeled wagon and a pair of brewer's horses to haul a quarter of a load to the market. If any proof is required of the financial mistake of constructing lines of gauges in excess of the duty required of them, it is to be found on our branch lines. On arriving at a junction of one of the latter with a main line, it is a common circumstance to witness an engine of the same size and power as the one which has hauled an express train of sixteen or seventeen carriages coupled to two carriages and a guard's van. The haulage power remains constant whether the load is a maximum or a minimum. It is no wonder that branch lines live on the parent one; if they did not they would speedily collapse, as they do not, one out of twenty, possess independent means of existence and support.

The objection which is now raised against the construction of the small gauge lines in India is the same which has always been put forward under similar circumstances. It is the break of gauge. This has always been the bugbear attending the introduction of a small gauge when a larger one is already in existence, and its effect has been to cause companies and shareholders to persist in an error, instead of acknowledging it and setting to work to rectify it. That a break of gauge is not a circumstance to be desired, any more than a change of carriage, although the latter may involve no greater hardship than stepping out of one carriage, walking a few yards, and getting into another, every one will admit. But on this account alone to adhere to a system which past experience has proved beyond the possibility of doubt to be false in both theory and practice, is the extreme of folly. If the question of a break of gauge be inquired into, it will be found to be little more than an inconvenience at the most. So far as passengers are concerned it resolves itself simply into a change of carriage, and this happens on railways of a uniform gauge, as a rule, at every junction station to the traveller quitting the main line for the branch line or *vice versa*. With goods traffic the case need not present any much greater difficulty. It is needless to remark that the old idea, which is still entertained by some, that the contents of the one whole goods train, truck by truck, would have to be transferred in detail into those of the other, has long ago exploded. The only trucks that would ever be filled, or packed with goods, would be those belonging to the smaller gauge. On arriving at a junction these would be lifted by cranes bodily off their frames into the larger trucks—or the equivalent of such trucks, probably only frames, wheels, and axles—without the contents of the former being in any manner disturbed. The reverse of the operation would attend the return journey. The larger trucks and wagons would, in

fact, except where their contents were consigned to stations on their own gauge, act merely as carriers of their smaller brethren. There would, of course, be no difficulty in arranging the relative dimensions of the different sized trucks, so that two or more of the smaller might fit into one of the larger without the loss of any appreciable carrying space. We will not now dispute whether the construction of the existing railways in India on the 5 ft. 6 in. gauge was an error or not. We are inclined to think not; but of one thing we are quite certain—it is, that the construction of future lines on a gauge of that magnitude would be a very serious blunder, and one that might eventually paralyze the further prosecution of railways in a country in which they are so greatly needed. No doubt, when once a certain plan has been laid down, and a certain system proposed to be adhered to, it requires some determination and sound judgment on the part of those who are responsible for the course hitherto adopted, to admit that a continuance of it would be prejudicial to the interests of the country. The more credit is therefore due to them for the acknowledgment, and their endeavor to rectify whatever mistake may have been committed. The introduction of the small gauge lines in India will develop the resources of that vast empire to a degree to which all previous attempts will bear no comparison.

THE STORY OF THE SEVEN-INCH GUN.

From "The Mechanics' Magazine."

Admiral Sir Leopold McClintock, F.R.S., Superintendent of Portsmouth Dockyard, presided lately at a meeting of the officers of the two services at Portsmouth Dockyard, on Friday, 17th May, when Commander William Dawson, R. N., told the story of the 7-in. gun. He said:

"The ablest artillery authorities are agreed that a new system of rifling must be sought for the heavier guns if they are to throw shells of adequate length, and to endure rapid continuous fire, such as they will be subject to in well-contested naval actions or in bombardments. It behooves artillerists, then, to study the mechanical principles which distinguish the few systems of rifling which have been successfully tested, with a view to observing their relative merits, and to forming intelligent opinions on such schemes as may be presented for adoption. Now, seamen have great opportunities of close observation, and, if they will only collect and collate numerous facts, may add greatly to the stores of knowledge, and they may enable artillerists to deduce from those facts some of the true principles of science. After the expenditure of two and a-half millions sterling in five years, the Duke of Somerset confessed, in 1863, that the country had no better gun than the 68-pounder; and although the Armstrong projectiles had been tried, there was no prospect of supplying our iron-clads with heavy rifled guns, and, in despair, the Admiralty insisted upon having various heavy smooth bores.

"Thus matters stood when, in 1863, a heavy gun competition was determined upon with a view of ascertaining which of five competing systems of rifling, viz., the Bashley Britten, Jeffery, Lancaster, Scott, and the French or Woolwich, should be preferred. Four Land Service 7-in. guns of 7½ tons were accordingly rifled on these principles. From various causes the competition dwindled down to a trial between the French and the Scott gun. And of these it was reported that 'the shooting qualities of these guns are so nearly alike that the Committee feel they may rest their recommendations of the one or the other system upon other and more general considerations, and they have finally determined to record their unanimous opinion in favor of the so-called French system: 1st, because of the simplicity of its studding on the projectiles; 2d, the simplicity of the grooving; and 3d, from a disposition to admit of the advantage of an increasing over a uniform spiral, which has been strengthened by the present trial. This advantage can best be realized with a short bearing on two points.' The French gun itself gave a somewhat different report, for, being examined by the Inspector of Ordnance after the 567th round, the upper groove was found cracked for 8 in. in length, just where the upper foremost stud

struck it in starting; dents were found in the lands and grooves, about the same spot; the loading side of the lower groove, for a length of 12 in., just where the lower stud in coming into bearing inflicts a heavy blow on the rifling, was much worn; about the same point, viz., from 15 in. to 33 in. from the bottom of the bore, the bore was enlarged as much as .049 in.; and such other injuries were inflicted by its wobbling projectiles that (the Inspector said) 'this gun should, in future, be fired "under precaution."' Thus, at the 567th round, the gun with the three merits enumerated was added to the 'Cemetery of Suicides.' On the other hand, the Scott gun, which had fired 417 iron-ribbed centring projectiles, had its grooves and lands as perfect as when it left the factory, the only damages being those common to both, and due to the conical form of chamber, the destructive qualities of which were not then understood. The Admiralty (advised, no doubt, by the then Captain of the Excellent, the present Admiral A. Cooper Key), preferring the report which the projectiles had written in their respective guns to that emanating from the Committee, asked to have Scott's gun sent to the Excellent for further trial; but the President of the Committee anticipated the application by boring up the gun to 8.03 in. bore, by which it was rendered utterly useless for any purpose whatever from that day to this."

After describing the "simplicity" of the Scott centring iron-bearing projectile, and the peculiarities of its construction, Commander Dawson proceeded: "The distribution of strain and the perfect centring in the bore fully account for the grooves having been as perfect at the end of the competition as when the gun left the factory. It also explains why the centring shot of the same weight, fired with similar charges, escaped out of its gun so much more readily than the French or Woolwich one, striking a far heavier blow. Thus, with 110-lb. shot, the Scott gun struck, with a 25-lb. charge, a muzzle blow 133 ft.-tons heavier than its rival; with a 20-lb. charge, it struck a blow 121 ft.-tons heavier; and, with a 12-lb. charge, it struck a blow 27 ft.-tons heavier. No wonder that the Committee reported that 'the French gun has decidedly the lowest velocities.'

"Thwarted in their desire to test the Scott gun on board the Excellent, the Admiralty next objected, in 1865, to the increasing spiral which had no doubt aided in producing such deplorable results in the French competitive gun; and, 'at the request of His Grace the Duke of Somerset, who desired to test the relative qualities of increasing and uniform twists,' two 7-in. 6½-ton guns were tried with French or Woolwich rifling, but with the two kinds of spirals, each ending in one turn in 37 calibres. It was found that by adopting a uniform spiral the velocity of muzzle blow of the French rifled gun, using 115½-lb. shot and 22-lb. charges, might be increased 21.2 ft., or 56 ft.-tons; and that then 'the blow struck by the one shot on leaving the muzzle, would be to that struck by the other as 100 to 103.' Even then the muzzle blow of the uniform spiral 7-in. French gun was 196 ft.-tons less than that given by the Scott gun—albeit, this French gun was one ton lighter. Strange to say, the Committee still held to their third merit of the French gun, viz., 'a disposition to admit of the advantage of an increasing over a uniform spiral.' But the Admiralty, backed no doubt, by the Captain of the Excellent, and encouraged by dissentient artillery officers, were obdurate, and would not have what was then regarded as the only heavy broadside gun rifled with an increasing spiral. The War Department, though silenced as to the 7-in. gun, was not convinced; and, persisting in 'the disposition to admit of the advantage of an increasing over a uniform spiral,' ultimately succeeded in having their own way with the heavier guns subsequently introduced. Though the adoption of the uniform spiral 7-in. French rifled guns has prolonged their lives far beyond that of their illustrious ancestor, the disabled competitive gun, it has not wholly counteracted the decay of nature. The grooves of the 7-in. guns of the Favorite were found marked by the over-riding of studs when that ship returned from the West Indies. The 7-in. gun of the Redwing was found split at the muzzle at the 881st round; another in the Warrior had its bore dented by its projectiles; and a fourth, in the Royal Oak, was found similarly injured. A 7-in. 68-pounder of 95 cwt. had the inner part of its grooves enlarged by the action of the studs, in 1871; and in 1870, another similar gun was, by the action of its wriggling projectile, burst violently at the first round in 76 pieces, which were thrown over an area of 580

yards by 150 yards. Still, as compared with the original 7-in. gun with increasing spiral, the endurance may be regarded as very tolerable.

"But endurance is not the only quality required in a good naval gun. The problem is, 'How to evolve the maximum amount of useful work out of a given weight of gun.' Now, a shell perforated with two rings of holes, each 3 in. deep, and 1.6 in. diameter, into which gun metal studs are swedged cold, and upon which the whole effort of rotation is concentrated, must have much thicker walls, and consequently much smaller powder capacity, to be equally strong with a shell which has no such weakening holes, but has iron flanges of strengthening buttresses cast upon its outside. Again, the object of rifling a gun at all is to spin the projectile so perfectly that it shall 'sleep' like a boy's peg-top when well spun, and not wobble like the same top when badly spun. A well-spun shot flies through the air, point foremost, making a sharp 'whizzing' sound, such as every rifleman is familiar with. A sharp 'whiz' indicates that the bullet has been centred in the bore, and that the rifling has done its work well. But an intermittent 'puffing' noise in the air indicates eccentric gyrations, which have been impressed upon the projectile whilst still in the gun. A 'puffer' in the air is necessarily a 'wobbler' in the bore; and, though the 'puffer' reaches its destination in due time, its range is decreased by the expenditure of effort in 'dancing,' instead of walking the distance.

"Thus, it so happened that when Scott spoilt his iron-ribbed shot by putting on it a soft zinc facing, it gave, with a 29-lb. charge, 11 ft. less initial velocity than the 'French' or Woolwich one; but it was so much better rotated that at 5 deg. elevation it reached 97 yards farther, showing that the Woolwich studded shot had been expending much of its force in the 'giddy dance,' whilst the Scott shot was sticking to its work with becoming sobriety of demeanor. The original cause of difficulty of escape and of disproportionate range is not far to seek. As the Woolwich projectile sits in its seat in front of the powder charge, it rests upon the two lower studs, no other part of the shot touching the bore. The centre of the shot is, therefore, below the centre of the bore, and there is a considerable space above the shot, the loading side of the two lower studs touching that side of the lower groove. When the charge is ignited a horizontal blow is inflicted on the base of the shot above its centre, and the gases escaping above it strike also a downward blow in the rear. The shot being balanced on two studs has its rear struck downwards, and its front tipped upwards by the escaping gases. This originates a vertical hammering action, which shows itself sometimes by flattening the lower rear stud, by spiking the lower groove about 12 in. forward of the seat of the rear stud, by spiking the upper groove about 12 in. forward of the spot over the seat of the fore stud, by scoring the base of the shot, or by flattening in certain cases the seat of the shot. Moreover, the lower studs, resting at the bottom of a curved groove, necessarily come into bearing on the driving side before the other studs, which have a less deep hold of the other grooves. Each set of studs comes thus into driving bearing successively, imparting a succession of blows which result in a lateral wriggling motion. Should the lower rear stud have been flattened by the vertical blow of the escaping gases, it will come into driving bearing at a still earlier period than its fellows. As the projectile proceeds along the bore, another set of studs occupy the lower position, and as these have not suffered either from the vertical blow of the escaping gases or from the side blow of first coming into bearing, their force is unaltered, and they take the grooving at a less depth, again altering all the bearings of the several stud rows.

"We have thus a succession of lateral wriggling motions imparted to the projectile as it turns round in its passage along the bore. When an increasing spiral is superadded to the difficulties placed in the way of the shot's escape, it is evident that the muzzle strains must be greatly enhanced, and that the major part of the work of rotation must be borne by the one rear stud in the lower groove. Indeed, it has been found that, by cutting away the front studs and several of the rear ones, the wriggling is not so very much worse than when they are all present, showing that the work of rotation is really shared by very few of the studs. As the centre of the French shot does not rise to the centre of the piece, the principal powder action on its rear is above the centre all along the bore in its exit. So that we have in the

non-centring Woolwich stud system a maximum of lateral wriggling and vertical hammering, and a minimum of rotary power. The natural result is that the projectiles are imperfectly spun, and the sure index that it is so is the 'puffing' noise with which every naval officer is familiar. But bal spinning necessitates a short shell or a short range. The double shell for the 7-in. gun is not 4 calibres in length, and contains only 12¾ lbs. bursting charge. Yet we are officially told that 'these shells roll considerably,' and that 'it is not contemplated to fire it at long ranges, as its flight would be inaccurate.' In other words, this shell would go flop (broadside on) against an object only 1,000 yards distant, and would have, therefore, little or no penetration. The obvious means of remedying this fault would be to increase the angle of spiral in the gun, as Sir Joseph Whitworth has proved that even with a long bearing in each groove, one turn in 35 calibres is only sufficient for projectiles 3 calibres in length, and that one turn in 23 calibres will, if properly gripped, spin a shot of 5 diameters. But this expedient cannot be resorted to on the stud system, as neither the grooves nor projectiles will stand so rapid a twist.

"The highest artillery authorities are alive to this failure of rotation; and the question of long-bearing centring projectiles versus the short-bearing non-centring system, is under consideration. Are naval men, with all their great experience, so incompetent to pronounce upon their own weapons, that its decision will be left in the hands of a committee composed of six military men, with one naval officer to preserve appearances? So long as the Navy does its duty in keeping hostile fleets afar off, no military gunner will ever have an opportunity of firing a hostile shot from a heavy gun.

"But in performing this duty we shall have to use these heavy guns pretty freely. Does the one naval voice to six military ones fairly represent the past experience or the future service of the two professions in the use of heavy guns? The simple explanation of this anomaly is, that what our military brethren lack in experience they make up in knowledge. And if the Navy is to hold its own in professional matters, it must proclaim open war against ignorance of science, and, taking to heart the motto of the Junior Naval Professional Association, remember that 'Knowledge is Power.'"

ECONOMY OF FUEL IN STEAM NAVIGATION.*

By MR. F. J. BRAMWELL.

From "Engineering."

The writer stated that he had often been struck by the indifference to the question of economy in fuel which for so many years prevailed among the constructors and the users of marine steam engines, and by the fact that, whilst wonderful progress was made in the increase of the speed of the ships, the quantity of fuel burned seemed not to be cared about, and excess in this respect was not looked upon as a reproach to marine engineering. In these days, when ships were tried for speed at the measured mile so carefully, to ascertain the last portion of a knot that could be got out of them, the question as to the quantity of coals burned in obtaining this speed was never raised, and the suggestion that there was still a more important trial to be made —a trial as to the consumption of fuel—was never thrown out. The astonishment that was felt on looking back at this long-continued apathy as to the consumption in marine propulsion was increased when it was considered that the mine owner, the water works engineer, the locomotive superintendent, and—last, by no means least—the manufacturer of portable agricultural engines, had all along been trying to find out to what extent economy could be obtained, although not one of them had really so much cause to search after saving as had the proprietors of ocean-going steamers or the builders of marine engines. He believed this indifference to have arisen from various causes, amongst which was the fact that steam navigation in the outset was confined to coasting voyages or passages across the Channel, and, under the circumstances, the quantity of coal to be

* Abstract of paper read before the Institution of Mechanical Engineers at Liverpool.

stored in the bunkers was comparatively small, whilst owners were content with a very slow rate of speed. The opening of new outlets for industry, requiring boats that could perform long voyages, led to a demand on the part of steamship owners for more economical steam engines. There was a general opinion that marine engines were not suitable for the use of high-pressure steam; but compound engines having been tried, with the use of high-pressure steam, the beneficial results obtained induced owners almost universally to adopt them for vessels going long voyages; indeed, so great were the advantages found to be, that most of the large steamboat companies had the original single-cylinder engines in their existing ships replaced by compound ones. It was still an open question, however, whether the same effect obtained by the compound cylinder could not be obtained by the single cylinder working expansively, either arranged so that the expansion could not be tampered with, or else put into the hands of truly intelligent men who would not throw the expansion out of the gear. Theoretically, there could be no doubt that steam could be as advantageously expanded in one cylinder as in two, and even more advantageously, on account of a certain loss in the passages between the two cylinders of the compound engine, which loss did not arise when the expansion was made all in one cylinder.

The writer then proceeded to trace out the history of the compound engine, describing the various arrangements which have been from time to time brought into use, such as the original arrangement of Woolf, the modified plan of McNaught, and the various forms which have been given to compound engines as applied to marine purposes. The last arrangement described was that now most generally adopted for commercial steamships, namely, the steam hammer type, with but two cylinders and an intermediate receiver. Mr. Bramwell also showed that, whereas the average consumption of the best marine engines of nine years ago was 4.5 lbs. of fuel per horse power, the same results were now obtained with a consumption of 2.03 lbs. The construction of marine boilers for bearing higher pressure, he said, was a subject of essential importance in efficiently carrying out the advantages of high expansion in compound engines, and in connection with that subject there were important questions, such as care in the manufacture of the plates, their thickness and durability, and other matters; but they could not be entered upon in this paper.

In the discussion which followed, Mr. Jamieson said there was no doubt there had been very great changes in engines since 1854, much greater even than Mr. Bramwell had stated. He was now aware of four-cylinder engines working with one-third of fuel used for engines in 1855. In a voyage to Valparaiso and Panama and back in the mail service in 1855 the consumption of coal was 1,080 to 1,200 tons, and this had been reduced to 550 and 600, and even to 300 and 400. No doubt a great deal had been done in the last ten years, and even in the last five years, and it would be well to look at the effect of the adoption of the cylinder engines on commerce. It was evident that the compound engine was the engine of the day for marine purposes, and in the future, attention must be directed to the further improvement of the engine and the boiler connected with it, with a view to a greater reduction in the economy of fuel. They must see if they could not get a better boiler, and a forced combustion in smaller tubes. He had reason to believe that in the next decade they would see the figures reduced as much as in the last.

Mr. Crampton urged that the only test of the performance of an engine which they should take into consideration was the amount of water or weight of steam used per indicated horse power per hour. The quantity of coal used to evaporate that water depended upon the quality of the boiler, and in considering the performance of the engine it should be left out of the question altogether. Mr. Crampton proceeded to describe a series of experiments he had carried out on a small pumping engine doing an uniform duty, and capable of being worked with steam at pressures varying from 35 lbs. to 70 lbs. per sq. in. The experiments were made with steam at the different pressures, the degree of expansion being varied, so that in each case the engine was made to develop the same effective power. Each experiment lasted a week, and the results at which Mr. Crampton arrived were, that practically nothing was to be gained by employing steam of more than about 40 lbs. pressure expanded six-fold. He also subsequently pointed out the importance of

employing heavy reciprocating parts in single-cylinder engines working very expansively, and stated that in the case of the pumping engine to which he had alluded, the great length of the pump rods caused the reciprocating weight to be unusually large.

Mr. Thomson, in answer to an inquiry as to why some single cylinder marine engines, which had been built to work with high degrees of expansion had not succeeded, stated that the engines were given up in consequence of its being found impossible to get the valve gear to stand properly.

Mr Head called attention to the practice of stoking by hand. He said he had never seen a stoker putting on coal in front of a blazing fire without thinking that it was a practice which ought to be put a stop to. He was told that not more than one man in three could endure the work in tropical climates, and that in the Red Sea it was not unfrequent to see the firemen drop down dead at their work. He appealed to the authority of Professor Huxley in saying that a human being who was undergoing severe physical exertions in extreme heat lost 2 lbs. or 6 lbs. in weight per hour. The application of steam power was brought very near to the stoke-hole, and the operation of taking up coal and putting it on the fire seemed only to require a little mechanical skill. It was not more complex than what had been achieved in the construction of the sewing machine, the steam plough, and many other applications of steam power. In the interests of engineering, and also of common humanity, attention ought to be directed to the subject, and he should be glad to know from the marine engineers present whether there was any prospect of mechanical firing being applied to marine engines.

The President said the subject just introduced was, no doubt, a very important one, and he hoped that some day it would be fully discussed. But the subject before the meeting was the construction of engines, and it was impossible to deal at that time with all the branches of marine engineering.

Mr. William Laird said the firm of which he was a member had been engaged for many years in the construction of engines, and of late years they had found that nothing but the compound engines were called for for commercial purposes. The great economy which had followed their introduction had been of such immense advantage to those who had applied them that the compound engines had really displaced altogether the old system of engines. In some cases an opportunity had been afforded of testing practically the economy obtained in the use of compound engines as compared with the old system, by the substitution of the modern for the old engine in the refitting of ships, and the result in a series of voyages had been that the quantity of coal consumed was about one-half the consumption with engines of the old type. This, he thought, was conclusive proof that the adoption of the compound engines had been of immense benefit to commerce, and the result was that almost all the large steamship owners in Liverpool had more or less adopted them for their vessels. In some companies all vessels refitted had been supplied with the compound engines, while they had been adopted in the new vessels. Without entering into details, he merely wished to intimate the general and successful adoption of the compound engines, and he felt satisfied that if they receded from the stage at which they had now arrived, and used a lower pressure for engines or another system, they would make a great mistake.

Mr. Crampton said that in the statement made by Mr. William Laird the point was ignored that the engine taken out might be the worst type of single-cylinder engine.

Mr. William Laird said, in making the statement, he only meant to show how generally the compound engine had been adopted in Liverpool, and he thought it was sufficient to put the matter in a general way. Perhaps his way of stating the matter gave too great an advantage to the engines on the compound system. He merely mentioned the fact to show, in a commercial sense, the great advantage which had been gained through the introduction of the compound engines, and the state of perfection to which they had been brought by engineers throughout the country. He did not intend to claim any special credit for Liverpool.

The President asked Mr. Laird whether the old engines to which he referred were in all cases very old engines, or whether they were tolerably good engines of their kind.

Mr. Laird said they were good engines of the old type.

Mr. Ramsbottom said, as to the abstract view of the question there was no room

perhaps for two opinions, as far as theory went, because no doubt an advantage was to be derived from the increased pressure of steam, and from its earlier cutting off; but whether it was done by one cylinder or two was, he thought, a matter of very little consequence. It became a question whether they could get materials which would do something more than the materials now known; but he thought they had pretty nearly reached the practical limits of commercial economy. He did not think they were likely to reduce their pressure much below what they had now attained, and he should be glad to see that they were likely to increase materially upon it. If they could find materials, the mode of construction would be speedily hit upon, and they might look for higher pressure and corresponding economy. With regard to experiments, those which were isolated, and of merely a few hours duration, were of very little value. He attached very little importance to speed mile trips, the truest and safest results being, he thought, found in more lengthened working, such as actual sea voyages.

Mr. Bramwell, in replying on the discussion, said he thought there had been too much of the tone of finality about it. With regard to the observations of Mr. Ramsbottom in depreciation of mile trials, and in favor of long voyage trials, he most entirely agreed with him, if the thing to be tried was not a steamboat. He thought a six hours trial, carefully conducted, was a better test of what engines could do in the way of economy of fuel than the test to be derived from a long voyage. Assuming that the continuous indicator could be relied upon for giving good results, he trusted that steamship owners would go to the expense of fitting their steamers with implements of that kind, so as to arrive at truthful results. The getting a better evaporation of water for the fuel burnt was at the root of economy. As to mechanical stoking, alluded to by Mr. Head, he most thoroughly agreed with the suggestion, and he could not help thinking that it was a problem which ought to be solved. If they succeeded in doing so they might get a more regular combustion of fuel. At the shows of the Royal Society he had seen as many as from 35 to 40 firings in an hour; they endeavored to get by rapidity of hand stoking the uniform and good effects obtained from efficient apparatus. Mr. Bramwell also deprecated anything like finality in scientific discussions, and in illustration quoted some exceedingly amusing extracts from evidence given by some of the leading engineers early in the present century on the occasion of a Parliamentary inquiry, this evidence going to show that the use of steam of higher pressures than 4 or 5 lbs. was unnecessary and absurd, and that cast iron was far preferable to wrought iron as a material for boiler making, although one witness admitted that wrought-iron boilers possessed one advantage, inasmuch as "each rivet formed a safety valve.".

The President, in proposing a vote of thanks to Mr. Bramwell for his paper, said, if a general conclusion might be drawn from the subject discussed, he thought it would amount to this, that the compound engine enabled them to press the steam higher than they could do practically with a single-cylinder engine. As to the mode of firing at agricultural shows, and the remarkable results which were there obtained, that mode of firing would be wholly inapplicable to marine engines, where they had to deal with enormous quantities of fuel under circumstances very onerous to the men who had to attend to the fires. He quite agreed with Mr. Head that the problem of mechanical stoking was one which ought to be solved. He believed a great step in advance would be made, and that they would have improvements in connection with boilers, which would enable them to apply more thoroughly the heat, and destroy more completely that portion of the coal which was now driven out of the chimney without being burnt at all. He hoped that result would greet them when they met in London ten years hence.

Some extensive new lines of railway are now being constructed in New Zealand by Messrs. Brogden, who have engaged the services of a number of the Warwickshire farm laborers. The lines are—Auckland to Waikato, 41 miles, at £166,000; Invercargil to Mataura, 42 miles, at £86,000; Dunedin and Clutha, 34 miles, at £142,000; Wellington to Hutt, 8 miles, at £40,000; in all about 125 miles of railway at a cost of £434,000, rather less than £4,000 per mile.

A car load of coal can be unloaded into a barge at East St. Louis in 4 min.

EARLY HISTORY OF RAILWAYS AND ORIGIN OF GAUGE.*

Railways are old as civilization; stone ways, adapted to the passage of wheeled carriages, are still in existence in the vicinity of the Egyptain quarries, whence the massive stones were taken to build the Pyramids. Wooden railways have been used in the mining districts of Germany from time immemorial; they were introduced into England early in the seventeenth century, and to that country we are chiefly indebted for their improvement, and the development into that system which has become the life of commerce.

We find in the History of Coal Mining at Newcastle-upon-the-Tyne, as early as 1602, a complaint, in quaint old English language, of the increasing badness of the roads, by which the loads of carts were being reduced; and in 1649, an account of a Mr. Beaumont, who expended £30,000 in improving the ways and wagons, and in introducing rare engines for boring with iron rods, to try the thickness of the veins, and for removing water from the pits. In 1676, the ways are described as rails of timber, straight and parallel, on which bulky carts on four rollers, are moved with such ease that a horse will draw 4 or 5 tons; but not until 1765 do we hear of something like a regularly constructed railway, which was graded by cutting and filling and had wooden rails 7 in. sq., resting upon cross sleepers 4 ft. apart. We then have an improvement on this wagon-way, called a "double way," by which the number of cross-sleepers are doubled, and the rails are also doubled by placing one on the top of the other, with cinder packed between them. In 1770, the railway is described as a great work, carried over irregular ground, a distance of 9 or 10 miles, with wooden rails rounded on the top, and wheels made of cast iron, hollowed to fit the rounded surface. Then we have the rejection of the outer flanges of the metal wheels, the tread made flat, and iron placed on the curves to check the wear of the rails. In 1776, we have a cast-iron railway built in Sheffield, with flanges, projecting upwards, cast upon the rail, and both flanges on the wheels dispensed with; this was too great an improvement for the temper of the workpeople, who got up a riot and destroyed it.

Edge rails were introduced in 1789, which again restored the inside flange to the wheels, and, in 1800, Benjamin Ostram made the improvement of supporting the ends of the rails with stone instead of wood, which gave them the name of "Ostram roads," afterwards abbreviated to "Tram roads." Malleable iron rails were introduced in 1808.

All these roads had a gauge of 4 ft. 8½ in., which was the gauge of the ordinary road wagons to which they were originally adapted, and with which, from their slow progress, they long continued to be closely allied.

One hundred and fifty years of English experience had been required to advance them from timbers laid down to prevent the cart wheels from sinking in the mud to an iron rail and iron wheels, somewhat like the mode of the present day. Whilst Beaumont was expending his £30,000 at Newcastle, De Cans lay incarcerated in a madhouse at Paris for conceiving the idea that carriages could be moved by steam, calling to the people as they passed, "I am not mad! I am not mad! but have made a discovery!" The idea was expanded by James Watt in 1759, by Oliver Evans in 1772, and by William Symington in 1784.

The year 1800 found Tram roads so popular that they were talked of for general traffic; the Duke of Bridgewater saw "danger in them;" George Stephenson who had risen to the charge of a hoisting engine at the mouth of a coal pit, at the age of twenty, was slowly but surely developing.

We now find attention strongly turned to steam locomotion; in 1802 an attempt was made to introduce it on common roads, and in 1804 upon railroads, and the efforts continued with but little success until 1814, when the discovery was made that there was adhesion enough between the wheels and rails to produce motion, and cogs, chains, and similar cumbrous contrivances were rejected.

It is remarkable how the mechanical mind clung to the idea that the wheels of locomotives would fly around without producing motion, even after the reverse had been demonstrated by experiment. In 1814, George Stephenson made his first locomotive with smooth wheels, which drew eight

* A paper read by J. Dutton Steele, Civil Engineer, Member of the American Society of Civil Engineers.

loaded wagons up a grade of 12 ft. per mile; in 1815 he invented the steam blast, which doubled the power of his engine; and in 1816 he succeeded in producing an engine with simple and direct communication between the cylinders and the wheels, joint adhesion of all the wheels by horizontal connecting roads, and combustion excited by the exhaust steam. In 1818 we find him experimenting upon friction, and, in his own practical way, working out the problems upon which the success of the railway system depended.

The Stockton and Darlington Railroad, which was opened for traffic in 1825, was the most extensive railway enterprise thus far undertaken; it was 25 miles in length and had four inclined planes from half a mile to one mile in length, with intermediate grades of as much as 51 ft. per mile. We have a discussion as to the gauge of this road, between the engineer, George Stephenson, and the proprietors, in 1824, from which it seems the question was settled with reference to the probable interchange of rolling stock, and the gauge of existing roads, which was 4 ft. 8½ in.; the same gauge was afterwards adopted on the Liverpool and Manchester road. Previous to the opening of this road, Stephenson established a shop for the manufacture of locomotives at Newcastle, and it is worthy of remark that the capital he put in this establishment was a testimonial he had received from the coal mining interests of the vicinity for the invention of the safety lamp, which has been so generally accredited to Sir Humphrey Davy.

At that shop were built the locomotives which, at the opening of the Stockton and Darlington Railroad, so astonished the world by drawing 38 wagons, loaded with coal, merchandise and passengers, at the rate of 12 miles an hour.

The railroad excitement was now fairly ablaze; the canal and turnpike interests were alarmed; the land-owners were startled at the prospect of inroads, which capital stood ready to back. An advocate proclaims that railroads "would widen the circle of intercourse, form a new creation, and extend the limits of industry and joy," whilst an opponent asks, "what is to become of the turnpikes, the coach and harness makers, and the horse breeders; the smoke and noise and hiss and whirl would dismay the cattle grazing in the meadows or ploughing in the fields. They would be the most complete disturbers of the quiet and comfort of the kingdom that the ingenuity of man had invented." The contest waxed warm in Parliament over the incorporation of the Liverpool and Manchester Railroad, but warmer in the field between the surveyors and land-owners; the farm hands were sent out with pitchforks to drive off the engineers, who were stoned and their instruments broken. But we must leave George Stephenson and his friends with the difficulties they were so fully able to meet, and turn to America.

The railroad movement in the United States seems to have been coincident with the opening of the Stockton and Darlington Railroad. In 1827 we have an account of the opening of the Quincy Railroad in Massachusetts, extending from a granite quarry three miles to tide water, with a gauge of 5 ft.; and the Mauch Chunk road, in Pennsylvania, from the Lehigh coal mines, nine miles to the canal with a gauge of 3½ ft. The gauge of the former was probably induced by the wide and high wagon wheels used for moving heavy blocks of stone, whilst the latter is the gauge of the mining cars yet in use in that region. The Mauch Chunk road was built for a gravity road, and it has been so worked up to this time; mules were first used to haul back the empty cars, but stationary engines and inclined planes were afterwards substituted. We find the same gravity system, with nearly the same minimum grades, at work on some of the sections of the Stockton and Darlington Railroad two years earlier.

In 1827 we have the proceedings of a public meeting in Baltimore to forward the construction of a railroad thence to the Ohio River, and in 1828 the report of a Board, consisting af Col. S. H. Long, Capt. Wm. G. McNeill, and Dr. Wm. Howard, of the United States Engineers, appointed to reconnoitre the country to be traversed by it. Their report is elaborate and able, and is probably the most interesting document of its day on the subject of railways in America. It adopted Tredgold's recommendation of a 4½ ft. gauge, and defined with great clearness the topography of the country; but a remarkable feature in it is a want of appreciation of the forces to which railways would be subjected. The Board was afterwards commissioned to visit England to examine the railway system there.

About this time the invention of the Wi-

nans car seems to have made some diversion of the railway interests in its favor; it reduced friction one half, and on account of the great play provided for the axles they would adjust themselves to the radii of the curves. We have the most florid accounts of what a horse would draw in them, and curves were regarded as of small importance. It was thought these cars would do best with the flanges on the outside of the rails; hence the first track laid on the Baltimore and Ohio Railroad was of 4¼ ft. gauge for flanges outside, with very sharp curvatures.

But the railroad world was to be startled with another great event: the appearance, with a tubular boiler, of the "Rocket" on the rails of the Liverpool and Manchester Railroad in 1829, and the opening of that road for traffic in 1830. These events seem to have taken the breath out of our American railway magnates; the Commission to England did not report, but we find in 1830 a highly interesting and elaborate report from J. Knight on the subject of gauge, size of wheels, turning curves, etc.

Two miles of track had been laid on the Baltimore and Ohio Railroad for flanges outside, and some experimental cars had been run upon it, when an alarm note was sounded from England; a mistake had been made, the Winans car would run with flanges inside, and a model car was sent over. But doubts had already arisen as to the safety on any track, and this was the condition of affairs which brought Mr. Knight's strong mathematical mind to bear upon the subject, and produced his celebrated demonstration that the exact gauge for a railroad was 4 ft. 9¼ in.

It was the fashion of that day among engineers to criticise George Stephenson as a man of no science, but if a "principle in science is a rule in art," then was he a man of sience, for he created, without much aid from books, the most important rules of art which have governed railroad operations up to the present day.

Somewhat in this vein was Mr. Knight. He had met no one in England who could inform him on what principle the curves were turned; but he had observed that the wheels were conical, and he invented the "cone and cylinder" wheel—that is, a wheel with a flat tread, and a cone between the tread and the flange. The elements he had to deal with were, the radius of his carve, the diameter of his wheels, the play necessary for his cones between the tread and the flange, and all must be so arranged that an English locomotive of 4 ft. 8½ in. gauge could be used if necessary. He published his elaborate calculations, which resulted in a 30 in. wheel and a 4 ft. 9¼ in. gauge.

In 1835 Pambour visited the Liverpool and Manchester Railroad, and, referring to the question of the cone as the means of turning curves, says, "Thus far those means have been employed by approximation," and then, with a flourish of trumpets, gives the same rule for calculating that is found in Mr. Knight's report of 1830.

Gauge seems to have been chiefly a matter of local adaptation. Tredgold, writing in 1825, recommends 4½ ft. for heavy freight and 6 ft. for passengers; his argument rests entirely upon the necessity of keeping the centre of gravity of the cars safely within the rails. Knight works up to 4 ft. 9¼ in. in 1830 to suit his cones and short curves, and probably the gauge of 4 ft. 10 in. has resulted from an indisposition to deal with quarter inches. The compromise gauge which we are coming to between our 4 ft. 8½ in. and 4 ft. 10 in. "will be 4 ft. 9¼ in." —a less mathematical mode of reaching the result than Mr. Knight employed. We have next the excitement over the wide gauge on the grounds of higher speed and more room, and now over the narrow gauge on the basis of economy. The gauges of this country hereafter will probably be 4 ft. 9¼ in. and 3 ft., to be selected from local requirements; and the difference in the cost of building, equipping and working, and in the limits of capacity, will be nearly in proportion to the gauge.

In 1829 the Rocket made her debut in England with her tubular boiler; in 1830 the Liverpool and Manchester Railroad was opened, and the same year the first American engine appeared on American rails, built by Peter Cooper, of New York; it had a single cylinder of 3½ in. diameter, and run from Baltimore to Ellicott's Mills, a distance of 13 miles, with a car and 23 passengers, at a rate of from 5 to 18 miles per hour. This was soon followed by a working model from P. Davis, a watchmaker, of York, Penn., which was afterwards expanded into the well-known crab engine of the Baltimore and Ohio Railroad.

We meet here to-day upon the platform of mechanical progress. Forty-two years have elapsed, a period within the profes-

sional recollection of many here present, since the Rocket, the creation of an uneducated Northumberland miner, blazoned forth, bearing upon her escutcheon all the essential elements of a modern locomotive. There are now upon the surface of this globe of ours 125,000 miles of railroads, enough to girt the earth five times, and, there are plying upon them locomotives enough, if placed in a continuous line, to reach from New York to Chicago.

DYNAMITE AS AN ICE-BREAKER.

Translated from "Annales des Mines."

The intense and persistent cold of the last winter produced at certain points along the Rhone, fields of ice which threatened serious danger to many floating structures, if there should happen to be a sudden thaw with rise of the stream.

In view of this, in December last, the writer tried the effect of dynamite in breaking up and clearing the ice from the channel. The results of the experiments were so extraordinary as to justify their publication, with an account of the special dispositions made to obtain the maximum of effect.

The explosion of cartridges placed on the ice and covered with sand or mortar produced only a hole without long cracks, even along the line of least resistance; a result conforming with the usual effects of this substance. In order to detach large blocks from a mass of great superficial extent, the following method was employed:

At a distance of 14 metres from the free edge of the ice (which was from 18 to 20 centimetres thick) a channel was cut 1 metre long and 4 or 5 centimetres in depth, the section being in the form of a V. The face nearest the edge was vertical; the other was slightly inclined.

The dynamite was inclosed in a roll about 1 metre in length, and this was surrounded with sawdust and paper waste to prevent freezing. This was placed in the channel against the vertical face and was covered with sand from 3 to 4 centimetres deep, the greatest depth being over the slant side so as to direct the explosive force towards the vertical face.

The explosion produced several fissures, most of which were parallel to the edge of the ice and were from 40 to 50 metres long in either direction. In one case a fissure was made 58 metres long in one direction and 160 in the other. The charge was only 210 grammes of dynamite No. 3.

The blocks so detached were enormous; three or four making an area of 100 to 200 square metres. In order to break them into smaller blocks the following method was employed:

At the centre of the block, at about 8 metres from the edge, a hole was pierced 8 or 10 centimetres in diameter. In this was put an ordinary cartridge with fuse inclosed in a gutta-percha tube. To this was fastened a block of wood, which was placed across the hole so as to suspend the whole in the water.

Our experiments indicated that the most effective depth of cartridge was about 70 centimetres below the lower surface of the ice; unless it was very thick, when the depth should be less. The cartridges contained from 17 to 35 grammes of dynamite. The explosion lifted the ice and produced radiating fissures from 10 to 30 metres long.

This method alone serves to break continuous ice at a distance of 7 or 8 metres from the edge, but works better on detached masses.

The congelation of the dynamite must be avoided. It hardens at 70 Centigrade, and does not fulminate in this condition; so that it is well to surround the cartridge with sawdust, and to inclose in a second envelope of packing paper.

When the ice is soft so as to oppose less resistance sawdust should be mixed with the dynamite to diminish its force.

By this means in a single day we removed 50,000 square metres of ice. Four men were employed, and the expense was 40 francs.

At the Pioneer mine No. 2, at Shiler's Ferry, Mo., there are being raised large quantities of lead. At No. 3, on the Moreau, the great Scott mine is continuing to yield as rich returns as at first; and every foot the magnesian limestone series are penetrated with shafts of this company, the more extensive is the galena presented.

THE POLLUTION OF RIVERS.

From "The Engineer."

Whatever may be the law of the question, there can be no doubt that in equity there is no such thing as "a prescribed right to commit a nuisance." Yet this plea is one which is frequently advanced by those who have great interests at stake, and requires serious consideration at the hands of those who are intrusted with the administration of our sanitary laws and regulations. The principal sources of river pollution are town sewage and the refuse of manufacturing and industrial establishments. It would be difficult to decide which of these two sources in a town similar to Birmingham or Sheffield, is the more active in effecting a joint result which is acknowledged to be a serious evil. So far as the sewage portion of the nuisance is concerned, the matter has been taken in hand by the Government, and some progress has been made towards enforcing the fulfilment of conditions which will very much reduce, and perhaps in time altogether remove, the evil. At present it is the manufacturing difficulty with which we have to do, and but little thought is required to make evident the fact that the obstacles lying in the way when we attempt to dispose satisfactorily of manufacturing refuse, are far more serious than even those encountered in dealing with town sewage. With this difficulty the Legislature must deal very cautiously. While, on the one hand, it must not be shirked by those who should take active measures concerning it, on the other it cannot be summarily treated without doing manifest injustice towards those whose interests are thereby involved. The recommendation of the Rivers Pollution Commissioners has already begun to be felt, and it is intended that manufacturers, and proprietors of works in which chemical or other processes are carried on, are to be made amenable to the same regulations which are now made compulsory upon local boards and sewer authorities. So soon as Mr. Stansfield's bill has become law, it will be illegal to discharge any foul matter, refuse, or effluent fluid, into a stream, which shall lower its purity below a fixed standard prescribed by the Rivers Pollution Commissioners. There are some points in connection with the application of the sewage laws, so to term them, to manufacturers, that are deserving of attention. In the first place, is the standard too high, and does the Act partake of that arbitrary character which very frequently characterizes legislative enactments? The manufacturers very naturally assert that the standard is too high, and go so far as to state that it will be impossible for them to comply with the provisions of such a law without virtually closing their premises. In other words, according to their own statement, they cannot utilize their liquid refuse instead of turning it into the nearest stream, nor can they purify it to the degree which would render it legally right for them to dispose of it in the usual manner. Both of these pleas are raised, to some extent, upon good grounds. That just at the present moment manufacturers are taken somewhat aback by the stringent nature of the resolution, and are unwilling to try experiments which would entail considerable expense, must be admitted. But at the same time they in their turn must have some regard for those living in the vicinity of the rivers that are certainly polluted by their works, and for the property of the riparian proprietors and tenants, who have long been exposed to an evil which ought to be at least mitigated if it cannot be remedied.

There was a time when the refuse of gas works was esteemed of no account—in fact, of less than no account—for any one might take as much as he pleased, provided he only removed it from the premises. This same refuse can now be utilized in a profitable manner; and it has now to be seen whether the same course cannot be followed with similar advantage with every kind of waste and bye product resulting from manufacturing operations. But the trial must be made, or the question will never be solved. It remains to be proved whether manufacturers, with a fair regard to their own interests, can abstain from the practice they have hitherto adopted in getting rid of the refuse of their establishments, and employ another method more conducive to the interests of the community and the comfort and welfare of their immediate neighbors. It is our opinion that, if proper time be allowed them, they will not only be able to do what is required of them, but will ultimately find it to their advantage to do so. The utilization of sewage would never have ad-

vanced even to the limited extent it has, if it had been a matter of option. It is quite possible that some coercion may be necessary. It was not until injunctions were granted against offending parties—and, in a few instances, an actual sequestration of the local funds ordered by the local government authorities — that the responsible bodies became convinced that the question admitted of solution. The long immunity they had enjoyed begat the inevitable contempt which naturally follows, and they put their faith in the usual procrastination and indecision which invariably precedes the enforcement of all sanitary enactments and regulations. It is to be hoped that such will not be the case with the pollution of rivers by manufacturing refuse. The proprietors will have the good sense to perceive that they must make an effort to comply with the law, and at any rate endeavor to adopt a better system of dealing with their refuse and superfluous material, whether liquid or solid. It will universally be admitted that the subject is of sufficient national importance to justify experiments, even at some cost to those concerned; and it must be borne in mind that the man who tries and fails, is in a much better position than the man who never tries at all. The standard of purity laid down by the Commissioners is to the effect that "Any liquid containing in suspension more than one part by weight of dry organic matter in 100,000 parts by weight of the liquid, is inadmissible into any stream or natural watercourse." It must be admitted that generally this is rather a stringent provision; but when it is considered that not only do cattle, but human creatures drink from the streams which are so seriously polluted by offending parties, it is difficult to assert that it is more prohibitive than it ought to be. Besides, the real gist of the prohibition is to restore, if possible, our rivers and streams to their normal condition of purity. In spite of what the interested parties may assert to the contrary, we are convinced that they have little to do but to exercise their own ingenuity, and put their shoulders to the wheel, and they will very soon discover a mode of complying with the law which will not only relieve their neighbors from the evil under which they have so long suffered, but which may recoup themselves for any outlay they may have to incur. As the matter stands, socially speaking, it cannot be denied that the proprietors of manufacturing and industrial establishments make large fortunes out of certain materials, and those which are of no further use to them they send adrift, by no means to the benefit of the rest of the community.

The administration of a law is a very simple matter, and, as a rule, is carried out in its full intent and spirit. But the execution of the law is a very different affair, and it depends altogether upon the manner in which it is put in force, whether it be really efficient or becomes merely a dead letter. A considerable number of our laws are, as a fact, rendered completely null and void by the inefficient and evasive manner in which they are executed. It is of little use to lay down the law, if prompt action be not taken to enforce compliance with it. Probably no legal enactments are treated with so much general contempt as those pertaining to sanitary measures. The reason is to be found in the circumstance that the execution of the laws relating thereto, is vested in the power of those who very frequently have the strongest possible personal interest in not carrying them out. A flagrant instance of this kind was given in a leading article of ours a week or two ago. Whatever may be the conditions proposed in Mr. Stanfield's bill, or however stringently they may be enunciated, they will practically be inoperative if the executive power is to be vested in the persons whom that gentleman considers the best suited for the purpose. Mr. Stanfield proposes to confide to the justices the duty of detecting the pollution of our streams, and of imposing the penalties sanctioned by his Act; but this is probably equivalent to making the proprietor of a factory his own inspector. Supposing for a moment that the authorities mentioned were disinterested parties in the question, they are, nevertheless, utterly incompetent to the task, which is a very difficult one to perform justly. As a rule, they are men of very moderate scientific attainments, and totally unfit to be intrusted with the serious responsibility of deciding whether "the best practicable means of prevention or purification have been used." This very question is still undecided, and has for a long time engaged the attention of some of our most eminent chemists and engineers, and yet it is now to be summarily settled by men who have possibly never given a thought to it. When "the *best* practicable means" have been determined, it will be quite time enough to call upon incompetent judges to

enforce their adoption. The strongest objection to the appointment of justices, as the arbitrators in the case of river pollution, lies in the fact that in the manufacturing districts the majority of them must be directly or indirectly interested in the very causes upon which they are appointed to adjudicate. Imagine a whole board of justices trying such cases and giving their decision with similar actions pending against themselves. The realization of the idea, which is a very probable contigency, would be simply a malversation of justice. Moreover, the elasticity of the clause relating to the discretionary power vested in the justices is very remarkable. They can dismiss any case provided they are satisfied that "the best means" have been used, or that the nuisance complained of is "trivial," or "unappreciable," or "unavoidable." We imagine that they would generally be a very well satisfied bench, and contented to let matters take their course. It is needless to point out that to frame laws which are in themselves calculated really to benefit the public, and to intrust the execution of them to interested parties, is a mistake, and only tends to render inefficient that which should excite feelings of responsibility and respect. The proper official to supervise the execution of the law relating to the pollution of rivers and streams should be an independent person paid by the Government, and amenable to the same authority only for his actions. His salary should be sufficient to enable him to maintain the position of a gentleman, and his character should be such as to place him beyond the suspicion of being actuated by any motives in the discharge of his duty save those of integrity and impartiality. In the event of a complaint being lodged against a party, the official in question would investigate the matter, and if he found that the law was violated he would act in the capacity of a public prosecutor, and the plaintiff would thus be a mere witness. In the event of either party being dissatisfied with the decision, an appeal should be allowed to another jurisdiction. But it is very unlikely that matters would ever reach this point. The cases of river pollution which have hitherto presented themselves have not reached so great a pitch of refinement. They have been so flagrant and so palpable that the senses were quite sufficient to detect them without calling in the aid of the *savant* and the chemist. When the color of that which was once a clear current of water becomes as black as ink, and when the stream can be smelt long before it is visible, it seems a farce to analyze its contents in order to demonstrate their foul and contaminated condition. In order to maintain our rivers and streams in a pure, wholesome state, the refuse of manufactories must be treated in a manner which has not hitherto been adopted. The law does not concern itself about the means; it looks only to the end.

The sooner manufacturers in their own interests concern themselves about both, the better for themselves and the community in general.

FRICTION CLUTCHES FOR ROLLING MILLS.

From "The Engineer."

The papers "On Frictional Clutches for Rolling Mills," read during the recent meeting of the Iron and Steel Institute, as well as the discussion which followed, are remarkable for their intensely practical character. No one attempted to deal with the theory of the subject in hand, or did more than indicate in the fewest possible terms the nature of the conditions to be observed, or the principles on which a clutch suitable for rolling mills should be constructed. All that is to be gathered from the papers and discussion as a guide to those who would attempt to improve on existing clutches, is that the engine should be able to make from one-half to three-quarters of a revolution before the rolls start in either direction; and that both the Napier clutch, the Stevenson clutch, and Mr. Ramsbottom's system are capable of giving satisfaction to ironmasters. There was no theory talked at all; every man spoke of the things brought under his notice in the most matter-of-fact way, and therefore the papers and discussion are singularly circumscribed as regards interest. We shall endeavor to compensate as far as lies in our power for the deficiency, by investigating the questions connected

with reversing mills in a hardly less practical, albeit more comprehensive spirit.

Before it is possible to pronounce an opinion on the merits of any system of working reversing rolls, or to attempt to design a satisfactory system of reversing, it is essential that the nature of the work to be performed and the difficulties to be overcome should be fully mastered. The problem may be thus stated in its simplest form :—Given two cast-iron rolls, from 18 in. to 32 in. in diameter, and from 6 ft. to 10 ft. or 12 ft. long, required the means of causing these rolls to revolve in either direction at will, the change of motion to be effected with the minimum of noise and shock. Under the old system the crank shaft of a steam engine, always running in one direction, communicates motion to a system of spur wheels, so arranged that one shaft of the system in line with the rolls can be driven in either direction, just as one or other of two heavy pinions is fixed to it or runs loose on it. Each pinion is fixed to the shaft, or runs loose upon it, according to the position of a heavy double clutch, which, sliding on feathers in the shaft, or on a square on the shaft, so that it must rotate with the shaft, may be thrown into gear with one or other of two pinions running when the clutch is in mid position loose on the shaft in opposite directions. As the clutch is thrown into gear to the right or left it will rotate with one or other of the pinions, and so carry round the shaft and the rolls. A heavy shock takes place at the moment the claws of the clutches come into contact. To get rid of this shock is the special function of frictional clutches. Under this system very heavy and expensive gearing is required; pinions 8 ft. and 10 ft. in diameter, 2 ft. wide on the face and 7 in., 9 in., and even as much as 11 in. pitch being not unfrequently met with in heavy plate mills. To dispense with this, Mr. Ramsbottom, late of the London and North-Western Railway, introduced at Crewe a system of reversing in which two coupled high-speed, horizontal engines drove a large spur wheel on the roll shaft by means of a pinion on the crank shaft. No fly-wheel is used, and the rolls are reversed by reversing the engines, which is done with a link motion, as in locomotives. This system has been fairly successful in many respects, but is open to objections.

The shock to which the machinery is exposed when the old clutch system is used, is principally due to the fact that, at the moment of reversal, while the pinions are running at from thirty to fifty revolutions per minute—more usually the former speed — the rolls and shaft are standing still. When the clutch is thrown into gear with either pinion, the entire inertia of the roll shaft, the clutch, the coupling-boxes, and the rolls, has to be overcome, if not instantaneously, still within that fraction of a revolution allowed by the slackness of the clutch on the feathers, and of the coupling-boxes. The rolls are never running in one direction at the time of reversal, while the pinions are running in another. There is a heavy shock, which sometimes breaks the clutch. If the rolls, shaft, coupling-boxes, and clutch can be started gradually into motion, instead of suddenly, there will be no shock. The object of the friction clutch is to secure this end. The clutch, on being thrown into gear, is to slip until a certain point has been reached, when the rolls will begin to move very slowly, and they will then continue to move with a gradually accelerated pace, the amount of slip becoming less and less until the clutch and the rolls revolve at the same velocity. The action of a clutch in this way will effectually prevent shock. The problem is to make a clutch which will comply with the required conditions in practice. The first difficulty to encounter is this: the shock is due solely to the inertia of the rolls, etc., and the bite of the clutch must be so much less than the inertia of the rolls that that inertia will cause the clutch to slip in the first instance. But it is evident that if at any subsequent moment, when the iron is going through the rolls, the resistance should be greater in amount than the inertia of the rolls, that then the bite of the clutch will be too little, and the clutch will slip while the rolls stand still. If we attempt to overcome this difficulty by making the bite of the friction clutch great enough to carry the iron through, then it will bite hard enough to overcome the inertia of the rolls at once. In a word, it will not allow any slip, but will work like the claw clutch and give just as much shock to the gearing. The clutch, to be perfect, should be adjustable during rotation—that is to say, it should be slack at first, and go on getting tighter and tighter, until finally it was so tight that nothing which could be put between the rolls would cause it to slip. We are not aware that any clutch complying

fully with this condition is in use in rolling mills.

A favorite device for getting rid of shocks is to fit up the clutch-box with a system of springs or buffers. Such clutches have always failed in rolling mills. The springs do prevent shock, it is true, to a great extent; but once the rolls are started the springs relax, to be again compressed when the iron is going through, and the effect is, that instead of a rigid union existing between the engine shaft and the rolls we have an elastic union. The rolls move by jumps instead of uniformly, and it is impossible to do good work. For this, among other reasons, springs have been abandoned. They comply with but one condition of the problem. In order to show what perfect action in a clutch would be, we may describe an imaginary mechanical combination, which illustrates the points at issue very clearly. Let us suppose that to one horn of a clutch of considerable diameter the end of a curved piston-rod is fixed, and that to the opposing horn of the other half of the clutch a curved cylinder is attached, making up three-fourths of a circle. Let this cylinder be filled with water, and let the piston be at rest on the surface of the water. Furthermore, let an orifice of considerable size be made in the piston, by which the water can flow from one side to the other as the piston moves. This orifice must be controlled by a valve so regulated that as the piston moves in the cylinder the valve will close gradually, being quite shut when the piston is near the bottom of the cylinder. Fancy the cylinder fixed to the roll shaft, the piston to the engine shaft. Let us suppose the engine to begin to move at a uniform rate. The piston, meeting with little or no resistance, will at first move freely in the cylinder, the water passing through it; but the further the piston advances the greater the resistance becomes, because of the difficulty of forcing the water through a smaller and smaller orifice; so more and more strain is applied to the roll shaft, which at last begins to rotate slowly, and then faster and faster, until its speed is that of the engine shaft, or nearly so. It never can become precisely the same until the piston has reached such a point in the cylinder that the valve is quite closed; but once this point is reached, an incompressible bed of water will lie under the piston, and the clutches will then act as though they were metal to metal. A little reflection will show that such an action as the foregoing would render a clutch perfect. The difficulty is to apply the principle in practice.

The nature of the work to be done may be further illustrated by supposing a paddle-wheel to be hung over a tank of water so that its floats just touch the surface. Let this paddle-wheel be lowered by degrees until it is wholly immersed, and we shall have an exact paralled to the way in which the resistance of the rolls should constitute a gradually augmenting resistance to the engine. Neither of the clutches described, nor, in short, any frictional clutch whatever, can comply fully with the conditions satisfied by the water cylinder and piston. The best mode of illustrating the action of any adjustable friction clutch, that we can think of, is to suppose a locomotive slipping with a heavy load so that it cannot advance. Then let pig iron be piled on it until the adhesion becomes sufficient, and the engine will proceed. The frictional resistance between wheel and rail is supposed to increase gradually in direct proportion to the weight; but in practice we know that it would be impossible to hit on a point where the adhesion would be just sufficient, while it was certain that the tire and the rail did not cut each other. Friction clutches are always liable either to slip or to seize. We do not say that they are always slipping or seizing, but that either contingency can only be guarded against by the use of precautions which it is difficult to secure in the rough and heavy working of an iron rolling-mill. Neither Mr. Napier's nor Mr. Stevenson's ingenious arrangements comply with all the conditions of a perfect reversing clutch.

Mr. Ramsbottom's arrangement is open to the grave objection that it is extravagant in the consumption of steam, because expansion cannot be used to any except the most trifling extent. It does not wholly dispense with gearing, and there is, no doubt, a good deal of back lash and chatter when the gearing is at all worn. Still, where there is plenty of steam to spare, the arrangement possesses many desirable features which would incline us to adopt it in preference to any clutch gear yet introduced in practice. Whether it is as suitable for the production of the finest quality of plates as the old system, is an open question which we need not at present discuss. It is quite certain that we have by no means

reached finality in the matter of driving reversing rolling mills; and while we admit that Mr. Napier and Mr. Stevenson have done much to improve the machinery by which such mills are impelled, we also hold that there is plenty of opportunity for the inventors of clutches to produce something very much better.

DYNAMITE IN FRANCE.

From "Engineering."

At the present time, when the advocates of the various explosives, gun-cotton, dynamite, or lithofracteur, are pressing forward the claims of the several agents; when a hundred industries in this country are anxiously inquiring which is the best explosive they can employ, and how they may obtain it in sufficient quantity, and when a careful Government, anxious not to commit itself by injudicious haste, is deliberating on the subject with more than usual slowness, it is interesting to turn to France, and note what has already been done in that country with dynamite, in order that we may gain some further experience on the subject, and learn how far this explosive material may be used in safety, and with what effect it is employed. In the "Bulletin de la Société de l'Industrie Minérale," an important and able publication, there have recently appeared several reports upon the subject by MM. Chauselle, Griot and Grille, three well-known mining engineers.

At Firminy, excellent results have been obtained in the open quarries, both in excavating sandstone for building purposes, and in the alluvial deposits, in limestone, quartz, and mica schists, with clay more or less sandy, and in beds sometimes very compact, and difficult to attack; the useful effect of the class of dynamite known as No. 3 has been shown equal to that of two or three times that of ordinary blasting powder.

But it has been especially in sinking shafts that dynamite has been used with the greatest effect. In the Camille shaft from 1200 to 1500 gallons of water an hour were encountered, which hindered the work of the miners greatly. Tamping with the ordinary powder was impossible, and the difficulty was avoided by the use of dynamite, of which quality No. 1 was employed, as being more violent in its action and less affected by water—the matches were either tarred or laid in tubes of gutta percha. At first the rate of progress was from 16 to 20 ft. a month, but afterwards the advance rose to 32 ft. per month; whilst with common powder, and under similar conditions, only about 20 ft. were obtained. The advance was thus one and a half times that obtained with powder, whilst the cost was reduced in the same poportion, because the price of the explosive is reduced in proportion to the other expenses. In fissured and water-bearing rocks, the advance was increased almost threefold. As to the noxious effects of dynamite, the numerous trials made at Firminy show that the vapor is less disagreeable than that from ordinary powder, and that it is not more hurtful to life. The engineer of the mines at Firminy, without showing any desire to claim more for dynamite than can be fairly accorded to it, says that the advantages it offers, such as rapidity in excuting work, and in facilitating operations that would be almost impossible with common powder, are so great that they cannot be easily exaggerated.

In the Montrambert mines the employment of dynamite, limited at first to sinking one shaft, was afterwards extended to the construction of almost all the galleries in the rock, ordinary powder being, however, also used. Water-bearing strata are frequently encountered at Montrambert, and in these cases the dynamite is especially valuable. The engineer asserts that dynamite No. 1 is unaffected by water, in which dynamite No. 3 also explodes well, and he also states that the gases resulting from explosion are inoffensive. Thus, at the end of a heading where the ventilation was very imperfect, immediately after six charges of dynamite had been exploded simultaneously, the miners were able to enter the heading without inconvenience, and to remain there until all the smoke had disappeared. The general results from the employment of dynamite, as compared with ordinary powder at these mines, have been as follows: In sinking a shaft through very hard stone, a progress of 24.5 ft. was obtained in a month by using gunpowder

and dynamite. Through some means the supply of dynamite having failed, the progress for a month with common powder was 18.5 ft. This difference was exceeded in some cases. In the hard rocks of Montrambert the cost of ordinary powder per day per man was 15d., with dynamite it was increased to 20 and 22.5d., making a proportion of 1 to 1.50, but the rate of proggress being greater, this proportion is reduced to 1 to 1.12. In the water-bearing strata the rate of advance was doubled by dynamite. The engineer of the Montrambert mines states that the comparatively low results obtained by the employment of dynamite should be for the most part attributed to the want of skill in its use on the part of the workmen.

At the new shaft of Chana in the mines of the Society of the Loire, dynamite has been employed since last February. The first explosion did not touch the rock; it proved, however, that the gas produced by the explosion did not inconvenience the miners. Now the bottom of the shaft was at that time about 460 ft. from the ground level, and without any ventilation; with common powder the smoke did not disappear, and it was necessary to keep up a constant current of air. In the second place this explosion showed that dynamite could be discharged perfectly in water, because the hole was wet at the time of explosion. Subsequent trials having given only moderate results, the manager of the works was sent to the mines of Montrambert to study the best mode of employing the dynamite. Since his return, after having made himself acquainted with the method of using the explosive, the results obtained have been found very satisfactory. As many as twelve charges have been fired together in the water successfully, both with powders Nos. 1 and 3. With the latter it was necessary to work more rapidly; the only precaution necessary, was to cover the cartridge with a thickness of earth. We may compare the results obtained in this mine with dynamite, and with common powder. From the 1st to the 10th of April a depth of 11.7 ft., with a diameter of 14.4 ft., was driven, or during 15 days 16.5 ft. With the ordinary powder 13 ft. in 15 days was effected. On the other hand the cost per day, was with the dynamite, 18 francs, and with the powder 14.50 francs, or altogether an excess of the former of 52.50 francs during the 15 days, an insignificant sum compared with the total work, the price per metre run being 255 francs. Altogether, with a slight increase in cost, an increase in the progress of one-third was effected.

In sinking the central shafts, in the Ferrieries mining concessions, the advantage still lay with the dynamite, more marked on account of the hardness of the rocks and the quantity of water met with in the shaft.

ON BURNED OR CRYSTALLIZED IRON.

By H. CARON.

From the "Bulletin of the American Iron and Steel Association."

Many theories on certain supposed properties of iron have been founded upon imperfect observations, and have been generally accepted without verification. This mode of procedure does much to hinder true progress in metallurgy. I hope to be of some use by rectifying a few of the ideas which have been too lightly admitted.

One of the most inveterate prejudices is the following: When a bar of iron of good quality, fibrous and tenacious, has been heated to a welding heat, and is then allowed to cool slowly in the air, without being hammered, a metal is obtained which is brittle, both when warm and cold, and of which the fracture presents a very laminated and crystalline structure. Such iron is said to be burnt, and it is generally supposed that the metal has absorbed oxygen. Karsten himself, in his excellent "Treatise on Metallurgy," supposes that the iron in this state has been transformed into a lower oxide, of an unknown composition. This is the hypothesis at present held.

My first idea was by direct analysis to discover the cause of this phenomenon; but, in spite of all my efforts and precautions, I have not been able in this way to pronounce conclusively as to the facts of the case. The iron before as well as after heating, invariably contained oxygen, carbon, silicium,* etc.,

* It is, of course, understood that there is such a thing as perfectly pure iron. I speak merely of the iron with which I experimented.

but the proportions of these substances, at all times very small, appeared to be so nearly the same in the good and in the burnt iron, that my analysis did not permit me to draw any certain conclusions. I then had recourse to direct experiments, and it is of these that I now record the results.

A bar of Franche Comte iron, of which the strength and fibrous structure had been previously ascertained by the means ordinarily employed, was cut up into small pieces. Some of these were heated to a welding temperature in an ordinary forge; others, after being placed in a porcelain tube, were heated to approximately the same temperature in a current of hydrogen, or of nitrogen. After being cooled slowly, all the pieces, without exception, presented in their fracture the characteristic crystalline structure of burnt iron. Forged at a red heat, or broken in the cold, they retained the same properties, and the same defects. Heated to whiteness, they all returned to very nearly their pristine state.

The so-called burnt iron appears, therefore, to be obtained at will in either an oxidizing, neutral, or reducing atmosphere, and I believe it must be admitted, therefore, that the deterioration of the metal is not due to the absorption of a particular gas, but simply to the action of heat, which under certain conditions modifies the molecular constitution. It is also assumed that continued vibration renders iron crystalline and brittle. I have not gone into this subject thoroughly, but I may remark that the investigations made upon our railways, and especially those of the late De Senarmont, and La Chatelier, have shown that the fractures of tyres and axles can always be explained by either bad workmanship or the inferior quality of the iron employed. The crystalline appearance of bars of iron, axles, etc., broken in winter time, has led to a widespread notion—which is, however, equally erroneous—that under the influence of the cold of our winters iron becomes brittle. That we have more axles broken in winter than in summer, that the bones of men and of animals are also more easily fractured, is incontestable; but the cause of these more frequent accidents may be the increased hardness of the soil, the stiffening of the muscles, and the increased shock therefrom experienced when collisions take place. It is, therefore, by no means clear that crystallization observed in the fractured pieces is due to the lowering ot the temperature. If this be so, it would be necessary to suppose that a bar of iron crystalline at −20 deg. C., would resume its fibrous condition at +2.0 deg. C.

Several pieces of good bar iron I caused to be exposed to the intense cold of last winter, other pieces I inclosed in the ice well of Ch. Tellier, at Antueil, for three months, the temperature ranging from zero, to −18 deg. C. I have broken the pieces thus treated under a variety of conditions of temperature, some of them whilst still cold, others when they had regained several degrees above zero. Their breaking strain was the same as before the commencement of the experiments, and in no case was the structure crystalline.

I must, however, state that all my experiments were made with good iron; in the case of poor iron I do not doubt but that the brittleness may be materially augmented by exposure to cold.

PETROLEUM.

(*Continued from page 359.*)

III.

ON THE TRANSPORTATION OF OIL.

It has been the aim in these papers to note for general attention the improvements and advances made in all matters auxiliary to the business of producing oil; in the unlooked for discovery unexpected emergencies called for extraordinary efforts. Many undertakings brought to a successful end would otherwise have died the usual death of long consideration; but with the prospect of large and sudden gains, great risks were taken and great things accomplished.

In moving a product worth twenty millions annually, even the short distance from the wells to the railway, the ordinary team was soon found to be deficient in every way. Where the wells were situated near the railway, or even when distant at great elevation, the oil was readily handled by gravity; but where hills and valleys inter-

vened, and the distance was measured by miles, the teamster ruled supreme over his unhappy animals and the wretched road.

For the operation of piping the oil there is probably little or no precedent, the ordinary conveyance of water by heads being, as we propose to show, of small value in that relation.

A 4-in. cast-iron pipe with leaded joints laid six miles down Oil Creek from Titusville, in 1861, was such a terrific failure that the teamsters took a new lease of life for several years more. At length Mr. Vansyckel, of Titusville, built the first line of any length, from Pithole to Miller Farm Station, five and a half miles. It was built in the manner now generally adopted, using ordinary 2-in. well tubing, and had at first two intermediate pumping stations, which were subseqently abandoned as unnecessary.

To Mr. Henry Hurley, however, of New York, for his foresight of the value of the pipe as a means of transportation, as well as the courage and ability evinced in the rapid extension of his own, the purchase of other lines, and the thorough and effective organization of the whole, we must give the the credit of being the first to convert doubtful efforts into a permanent and unquestioned success.

There are probably to-day in the Pennsylvania oil region, nearly 200 miles of tubing in the main lines and connections of the pipe companies, at least one-half of this being in the connections between the wells and the main lines.

The operation of receiving the oil is quite simple, the receiving tanks for any district being placed so low that they will drain the well tanks, which are run off at stated intervals; where a well is lower than the receiving tank a small pump is run by the well engine.

From the receiving tanks the oil is pumped to the shipping tanks on the railway and drawn from them into the tank cars, the longest distance covered with a single pump being about 13 miles.

The success of this method of transportation, although heretofore unnoticed, deserves more than passing attention, when it is understood that the average delivering capacity of these 2-in. pipe lines is 45 bbls. or 1,935 gallons per hour, through a length of from five to twelve miles, and over elevations of from 300 to 400 ft.; it will be seen that the questions of pressure and required force are taken at once out of the old channels by the overwhelming predominance of the one element of friction.

In a main line of eleven miles in length (60,363 ft.), with an elevation of 403.82 ft. to overcome distant 8,000 ft. from the pump, and working with a velocity of 4 ft. per sec., the writer found the head to overcome friction by Weisbach's formula.

$$\left(.0144 + \frac{.0174}{\sqrt{v}}\right) \times \frac{l}{d} \times \frac{V^2}{5.4} = h'$$

h' = head required in feet.
v = velocity in feet per second.
l = length of line in feet.
d = diameter of pipe in inches.

to be 2,069.4 ft., making the total head required 2,473.22 ft., giving a pressure for water of 1,070.05 lbs., or for oil of 47 deg. Baume = 7.972 real gravity, a pressure of 853 lbs.

In practice this is found to be considerably in excess, where the route is carefully selected and the line properly laid; as these lines follow vertically the contour of the ground in a hilly country, this seems somewhat remarkable, and it may be mentioned that no account was taken of any increased friction for the rise of the line in many places above the mean gradient from the highest point to be overcome to the point of delivery.

While for economy all main lines are made "bee lines" from pump to shipping station, the writer has found that a careful attention to the route produced a more marked difference in the pressure at the pump than ordinary supposition would justify; he regrets that space will not permit him to enter more fully into details on this point, and in fact on many others of similar interest in this connection.

The cost of these lines, including connection to wells, receiving and shipping tanks, and all other expenses, will range between $3,500 and $4,500 per mile of main line.

The simplicity and accuracy of their management is shown by the following list of employees:

Two engineers relieve each other at the pump every twelve hours; one man receives the oil from the wells and keeps the gauges, two men receive and ship the oil at the railway station.

At 11.30 A. M. each day the pump is stopped and the gauge of the receiving tank telegraphed to the shipper; by comparing it with his gauges any loss or difference is at once detected. In this way 800

bbls. per day will be easily handled by five men and a general superintendent, that would require for the same work 150 two-horse teams, including with platform men the services of 200 men and 300 animals, to say nothing of the 800 packages.

Upon this preface it is desired to state two propositions.

1*st*. That a pipe line is the cheapest method of transporting any fluid on land for any distance long or short.

2*d*. That with crude and refined oil it is also the most expedient.

The first proposition is stated in general terms for the purpose of bringing to attention a fact not generally appreciated.

For instance, while it would be the cheapest method of transportation per mile for wine, alcohol, or any such fluid from New York to St. Louis, it would not be expedient, because there is not enough of either of them sent between those places.

But with crude and refined oil it is different, owing to the immense quantities that must be daily moved.

In the proof of the above propositions the facts presented concerning the working of the pipe lines are taken from the experience of actual practice, and may therefore be deemed reliable; the statements made in regard to other matters are open to the judgment of all.

There being no fluid transported of less value per pound than crude oil, and there being no long route over which more passes than from the oil region to the seaboard, it is considered that if the feasibility of a pipe line from the oil region to the city of New York is established, it would prove both the above propositions.

The distance by rail from New York to the oil region is 460 miles; as the lines between the pumping stations of the pipe can be drawn perfectly straight, we can safely reduce this to 420 miles; now if a pump large enough were placed in the oil region and pipe strong enough laid on the route, one pump could force it all the way, but the expense would be so enormous as to preclude its possibility; also if a very light pipe were laid and a pump placed every mile, the cost of the line would be very light, but the number of employees required would be fatal to any profit. It is evident that there is a mean somewhere between these two, a balance as it were between pounds of iron used in the construction and wages of men employed afterwards; the writer places this mean at twenty miles for the extreme length of a paying section; the points given hereafter open it for general consideration.

We would then upon the whole route to the seaboard have twenty-one sections of twenty miles each; let us consider the cost, requirements and capabilities of one section, and that will answer for all.

In the first place there are 18,000 bbls. of crude oil produced daily; of this production 8,000 crude goes daily to the seaboard in tank cars by four main lines—the Pennsylvania Railroad, the Philadelphia and Erie Railroad, the Erie Railway of New York, and the New York Central; and of the remaining 10,000 bbls., which is refined at Titusville, Cleveland, Buffalo, and Pittsburg, at least 8,000 more, daily, in barrels or tank cars for refined; the balance of 2,000 bbls. being distributed West and South. These figures will vary somewhat during the year, but are believed to fairly represent a yearly average.

This amount of oil is not equally divided among the four railroads above mentioned; but with the view of presenting the case in the least favorable aspect, let us suppose it so to be; this would give to each road 2,000 bbls. crude and 2,000 bbls. refined per day of twenty-four hours.

We have then 4,000 bbls. per day to transport 420 miles; can this be done with profit by pipe?

The usual method of estimating this proportion is as follows: An ordinary 2-in. pipe line costs $4,000 per mile, in the ratio of capable delivery this one would cost at least $8,000, or a total of $3,216,000, the interest of which at 6 per cent. is $192,960, and proportional running expenses $400,000 per annum, making nearly $600,000, which is the total such a line could be fairly expected to earn.

In making, however, a permanent way for the moving of this product there exists no necessity for following the expensive faults entailed on the oil region pipes by the constant shifting to reach new territory and by the increased cost of fuel and material.

If you will step with me into a tank-house and observe that end of 2-in. tubing out of which the oil is coming that has been forced thirteen miles, you will see it falling in a gentle stream almost perpendicular, and in size but half the diameter of the pipe; a tube of paper could deliver it as well,

while the iron of the tubing here is just as thick as at the pump where there is a pressure of 800 lbs. per sq. in.; the tube also at this point of delivery is only half full. Are there no air valves on the tops of the hills? No. Are there no traps for sediment in the valleys? No. Are there any stopcocks on the line? Yes, branches run off at right angles in several places. Are these free way stopcocks? No, they have the usual oval slit in the plug reducing the passage.

You observe also that the pipe at the tank makes two right-angled bends—one at bottom out of the ditch, and one at the top, where it runs over the several tanks and where a fresh system of stopcocks is devised to obstruct the progress of the oil.

Let us, therefore, with these facts in view make an estimate of the cost and capacity of our twenty mile section properly laid.

The area of internal section of a 3-in. pipe is 7.06858344, contents of line 20 miles or 105,600 ft. = 38776.32 gallons, or 901 bbls.

To deliver 3,600 bbls. in twenty-four hours would require a velocity of 5 ft. per sec. We should lay on our line two of these pipes (switching into each other at regular intervals for convenience of repairs, etc.); one for refined, the other for crude oil. This would give us a daily delivery of 7,200 bbls., largely in excess of what we want, but useful in cases of gradual or sudden increase of business or as permitting cessation when desired.

Following out the ideas of pressure obtained at the tank-house, we should divide our twenty miles into four parts and increase the diameter gradually from the pump to the tank; let us see what we should gain by this.

The head required to overcome the friction of this 3-in. line (without enlargement), by Weisbach's formula (which we have stated to be in excess of actual result in practice), would be as follows:

$$\left(.0144+\frac{.01746}{\sqrt{5}}\right)\times\frac{105600}{3}\times\frac{25}{5.4}=2473.9$$

But if the line be enlarged a quarter inch every five miles, we shall have as follows:

5 miles	3	inch	friction	head.....	618.5
5 "	3¼	"	"	"	570.9
5 "	3½	"	"	"	530.0
5 "	4	"	"	"	464.0
			Total.....		2183.4

being a saving in head of nearly 600 ft. It will readily be seen that an equivalent to this gain may be obtained by a reduction of the diameter of the pipe at the pump, or by an increased velocity.

Thus—

		Velocity.			Fric. Head.	Contents.
5 miles	2¾ inch	5 9 ft	per sec	...	674 9	187 bbls.
5 miles	3 "	5 0	"	....	618.5	225 2 "
5 miles	3¼ "	4.2	"	....	570.9	264.5 "
5 miles	3½ "	3.6	"	....	530.0	306 8 "
					2394 3	983.5

being still less than the friction head required for a continuous 3-in. pipe.

It will also be found that the reduced line contains 983.5 bbls. instead of 901, and the element of friction representing the greatest resistance to be overcome, the enlargement will simply cause a constant reduction of velocity, and therefore of friction and pressure.

In twenty miles of straight pipe there will probably be elevation to overcome. Let us assume 4,000 ft. as an extreme and add it to the head required.

We should then find the total head as follows:—

				Head.	Lbs. to sq. in.
At the pump		2¾ in.	pipe	2794 3 ft. =	1212
Beginning 2d	5 miles	3 in.	pipe	2119 4 ft. =	919
" 3d	5 "	3¼ "	"	1500.9 ft. =	651
" 4th	5 "	3½ "	"	930.0 ft. =	403

(It will be observed that the head of 400 ft. is carried through all the sections in the absence of the levels of any actual line, otherwise the heads for the last two or three sections would be much reduced.)

By multiplying the pressures given by the difference in specific gravity of water and the oil of commerce, .7,972, we have the following:

	Pressure lbs. per sq. in.	Thickness of metal in pipe.	Weight per ft.	B.W.G.
1st Section	969	.167 inch	6 709 lbs.	No. 8
2d do	735	.138 "	5.587 "	No. 10
3d do	521	.093 "	3.799 "	No. 13
4th do	322	.071 "	2.910 "	No. 15

Our first	section	will contain	177,117 lbs.	iron.
" 2d	"	" "	146,176 "	"
" 3d	"	" "	100,320 "	"
" 4th	"	" "	76,824 "	"
	Total.....		500,437 lbs.	

The weight of the line if made of the ordinary 2-in. tubing in the usual manner, would be 387,235 lbs., whereas its capacity for delivery would be but 1,000 bbls. per day against 3,600 in the line above calculated.*

* Special mention is made of this fact, because all past estimates in this matter have been based on the cost of the ordinary two-inch lines; there is no question that with the constant shifting they are the best to use in the oil region, but contain a great waste of iron for a permanent line.

The work of the line would equal 366,291,200 gallons raised one foot high in twenty-four hours, requiring for its exertion a horse-power of 77 for water and 62 for oil.

Tankage for 1,000 bbls. at the end of each section would allow a delay of eight hours for repairs and be ample for ordinary purposes.

From the data above given, we make the following estimate of the cost of the twenty-mile section:

500,437 lbs. iron in pipe, *a* 9c.	$45,039.33
10,000 lbs. thimbles and fittings, *a* 20c.	2,000.00
Laying pipe in trench 2 feet deep 6,400 rods, *a* 60c.	3,840 00
70 H. P. boiler and pump with station house complete	10,000.00
Telegraph line	2,000.00
1,000 bbl. tank (iron)	1,000.00
Sundries	1,120 66
	$65,000 00

As such a line could not be laid without a charter, nothing is allowed for right of way, including trespass and damages to fences and crops, together with cost of site for stations, it may from experience be safely put at $5,000.

The twenty-one sections to New York, at $70,000 each, would cost $1,470,000.

At the present rate of $1.65 per bbl. freight, 2,000 bbls. per day would return a yearly income of $990,000 less expenses, as follows:

Each station 2½ tons per day, *a* $5		78,750.00
Employees.		
1 Gen'l Supt.	$5,000	
Salaries gen'l office.	10,000	$88,500.00
21 Station Sup'rs.	31 500	
42 Engineers	42,000	$167,250.00
Annual net profit		822,750.00
		$990,000.00

Now for the cost of the present system of railway transportation, we have

The cost of car	$800
Iron tank. 3,900 gals = 91 bbls.	500
	$1,300

In handling the entire product on different railways there are not less than 1,800 tank cars, the proportionate number of which for 2,000 bbls. per day is 200 cars, involving a first cost of $260,000.

The annual cost of transportion, 460 miles, at 1¼ cents per ton per mile, for 2,000 bbls. would be $1,380 per day, or $414,000.

The present through rate of $1.65 would give the gross income of $990,000.

Summary.

	First outlay.	Total annual exp.	Net an. profit.
By rail.	$260,000	$414,000	$576,000
By pipe.	$1,470,000	$167,250	$822,750

The advantages of pipe lines might be enumerated as follows:

The clearing of a dangerous and bulky freight from the main trunk lines.

The perfect accuracy of gauge in delivery (a source of constant trouble at present).

The simplicity of record and management.

With such lines in operation, the refining would, of course, tend naturally to New York and the other seaboard termini.

There may exist great difficulties in the way of present accomplishment of this matter by reason of standing contracts and outlay already incurred in car transportation, but any objections on the ground either of mechanical impracticability or want of pecuniary return may as well be at once laid aside.

Well knowing the deceptive power of figures when used in estimates of this kind, the writer has carefully avoided any "nursing" of his views, and has endeavored to present such an outline that any one interested in the matter can fill in from experience his own calculations for the thorough investigation of the subject, which is one that will well repay close and honest attention, but can by no means be justly comprehended in general or hasty criticism.

IV.

ON THE USE OF HYDROCARBON, OR LIQUID FUELS.

At regular intervals during the past few years, the public has been duly informed by journal and newspaper that the successful use of this class of fuels is an accomplished fact; that some railway, or steamer, or manufactory has given them such satisfactory test as to insure in a short time their universal adoption.

In spite of all these assurances, we still find the fireman on the engine, the stoker on the vessel and in the manufactory, and to those who have not made it a subject of special consideration, some explanation at this time might possibly afford no small relief.

While the prospect for the successful introduction of liquid fuels is at present

extremely doubtful, it may be well to remark that next to "perpetual motion" there probably has not been such an "ignus fatuus" as this presented to inventors during the last century. Hundreds of patents bearing on the matter have been introduced and laid aside, and still they come at long intervals, even now, with strong asseverations of final and permanent success.

It would seem on first thought that relative heating powers could be readily decided at once and forever by an examination of the component parts of the fuel, but underneath all the propositions and claims of the new invention as yet advanced, seems to lie vaguely and mistily, but powerfully, this idea, that by some heretofore undiscovered law, or inexplicable power, or in some indefinable way, more heat can be produced from hydrocarbons than their chemical analysis would indicate, and that in this way they will become the competitors of coal.

It is a dangerous thing in this country to say that anything cannot be done; so that, without attempting that statement, we shall confine ourselves to a few facts with the hope of drawing investigation into those channels which present more chances for success.

Let us, therefore, set our facts in order, as follows:

Coal, (bit.) consists, carbon, 83; hyd., 5; ashes, 12; average petroleum, 45°; carbon, 85; hyd. 5 in., small residuum. 1 lb. carbon evolves 14,220 units of heat; 1 lb. hydrogen evolves 60,854 units of heat.

To which the writer wishes to add as follows:

Fuels whose combustion produces water by combination of oxygen and hydrogen, lose much in calorific power.

Hydrogen, although producing the largest quantity of heat of any known combustible, is powerless to produce a similarly high temperature under ordinary conditions.

In the use of steam the law is imperative, that as much heat is required for the decomposition of water as is evolved by the combustion of its constituents.

For the better consideration of these facts, let us take the result of some reliable experiments; they may be substantially condensed as follows:

Those made by Mr. Richardson, at Woolwich, England, giving as a result the heating power of petroleum as 1.53 times that of coal.

Those made at the Battery, New York, placing the same result at 2.35; and the efforts made to apply it in the Pennsylvania oil regions for the generation of steam power, at the well, not less than seventy or eighty separate patents being introduced, of which the writer gathered the results of some forty distinct attempts during a period of twelve months, in which the average results indicated the relative heating power of petroleum over coal as being from 1.75 to 2.5 times.

Owing to the difference in the composition of coals, the different gravities of oils and the varying attendant circumstances of their use, these figures are probably as close as we will ever come, and for the comprehension of the subject under existing circumstances they are certainly near enough.

Crude petroleum at $3.00 per bbl. costs over 1 cent per lb.; coal (bit) at the well, $5.00 per ton or ¼ cent per lb. As oil is worth to-day $3.60 at the well, and coal in the large cities not much less than $8.00 per ton, the remaining figures can be made at leisure.

For a complete comprehension of the *weak point* in the heating power of liquid fuels, the following extract from an Essay on the Heating Power of Ohio Coals, by T. C. Mendenhall, covers tersely the entire ground.

"The heating value of a fuel may be estimated in two ways, as calorific power and calorific intensity.

"By the former is meant the total quantity of heat developed in the combustion of a given weight of the substance, and by the latter, the maximum temperature developed in the process.

"It is plain that in the complete combustion of any fuel the absolute amount of heat developed is constant under any and all conditions, whether the process be rapid or slow, in air or in oxygen; but the result is quite different in the matter of temperature or thermometric intensity; this is very materially influenced by the nature of the products of combustion and the rapidity of the development of heat compared with the rapidity of its dissipation among surrounding objects.

"A fuel may have a high absolute heating power, and yet in consequence of the peculiar nature of the products of combustion may develop a low temperature; and again it may show a low heating power and a great thermometric intensity.

"We learn from experiment that the presence of hydrogen in considerable quantities in a fuel may tend to increase its calorific power, but not its calorific intensity. Hydrogen, which has more than four times the heating power of carbon, has a calorific intensity much less."

Almost all past efforts have been directed to the construction of a "burner," as it is called, for liquid fuel, and the idea prominent in all these attempts is, that by some complication of the apparatus, an increased amount of heat could be evolved.

A very simple arrangement of heavy cast iron, costing but a few dollars, and consisting of a pan in two halves, set in a frame, having the steam-jet lying between the pans, and the whole covered by a solid iron cover, with an opening in the top for the escape of the flame, will produce a thorough combustion with no escaping carbon, or, in other words, *burn the fluid all up.*

When this is accomplished, and no smoke comes from the stack, you have all the heat that is in the fuel.

We have seen a "burner" that was as costly and even more complex than the engine and boiler it was set to drive; the residuum which forms in time a spongy mass in the bottoms of the pans in the simple burner above described, is readily cleaned out, and the several parts of this arrangement being disconnected, and simply set one upon another in the fire-box, are readily removed and inspected. But had any of the majority of liquid fuel machines been long used without their attendant god-parents, their career would soon have been brought by the residuum to an untimely end.

We repeat this fact, that a very simple apparatus will effect the perfect combustion of hydrocarbons, because the difficulty of the successful termination of these efforts (independent of the question of economy) *does not lie there.*

It has been claimed (and we do not propose to question), that petroleum has been used in St. Louis in the smelting of iron with advantage and economy.

Whether its value consists in the action of gases which it generates or simply as a gas fuel, is uncertain; as the Cleveland furnaces, whose facilities for procuring oil are so much superior, still use coal, there yet remains a fair doubt as to whether it may not be but a special advantage to some particular ore or iron, and yet we should be pleased to see it a success.

Nevertheless it causes a suggestion of perhaps some value.

We all know that in the burning of liquid fuels a strong draft is required, that as a consequence of this much of the heat must necessarily pass out of the stack; any attempt to obviate this by return flues or similar devices causes a deposit of carbon, robbing the fuel and destroying the sensitiveness of the heating surface.

If a *boiler* could be constructed to avoid these difficulties, the loss of calorific intensity by escaping heat, would be much less; the comparative experimental results as before given show much more in favor of liquid fuel, and the possibility of an economical and successful use of shale oil be at least greatly increased.

Concerning the supply of petroleum in case of the adoption of liquid fuel, it is only necessary to say that experience has shown that it cannot be produced for less than $2.50 per bbl. actual cost, and that this fact, of course, places it out of the list of fuels, for any ordinary purpose.

Any success in this direction must be confined to the shale oils, while their heating capacity is somewhat inferior to petroleum, they can be produced from the inferior coals at a cost not exceeding $2.00 per bbl.

If this could be still further diminished, and a boiler constructed as proposed, something might be done even now with the shale oils. The relative value of fuels for smelting purposes is a subject not to be lightly taken up; those who have made such a special study will, probably, at some early day, give their testimony concerning the use of hydrocarbons. The necessity of constructing the furnaces with special reference to the use of the gas fuel will, undoubtedly, act as a bar to its early acceptance, and is, perhaps, the cause of its want of use in the Cleveland smelting.

It is stated that a large percentage of the calorific power of coal is wasted in the ordinary reduction of the ore, and that is assigned as a reason for using to advantage a more expensive article.

It may be well to consider that the shale oils will always compete with petroleum in the two all-important advantages of cheapness and unquestionably unlimited supply; while petroleum is used for illuminating purposes alone, these will not be sufficient to counterbalance its superiority, but when both are used for heating purposes, these

advantages constitute very powerful arguments in favor of the shale oils.

The petroleum market is and has always been very sensitive, its fluctuating exceeding, perhaps, any other equally standard article of commerce; but a slight increase in the consumption is liable to send it above any comfortable margin allowed for its rise, while in such case the shale oils will naturally occupy its place.

Any sober consideration of these facts will show at once that petroleum can never be relied upon as a marketable fuel, and consequently can never be used except in experiment, or for any extended period of time; if successful in this way, it is liable to be supplanted at any time by the shale oils.

It is the practice in most cases of smelting to bring the ore to the fuel; if petroleum is to be used the furnaces will be in the oil regions, and an attempt is being made in that direction to which we wish every success; if the shale oils are used they will be located as usual near the coal mines.

It is, perhaps, a question whether the additional hydrogen in the coal oils is productive of a greater heat from them than from the fuel itself, especially when considered with reference to calorific intensity; the great waste of heat in the use of coal, is undoubtedly the cause in this case of its apparent inferiority.

Take the following as an average analysis of the three fuels:

Petroleum—Carbon,	85.05	Hyd.	14 30	Residuum	65
Coal oil—Carbon...	83.04	Hyd.	12.31	Oxygen..	4 65
Coal—say	83	Hyd.	5	Ashes....	12.00

Of course these proportions will vary somewhat in different cases, but it is not difficult to deduce from them, even at the present stage of experiment, that any superiority of the liquid fuels is due more to the peculiar possibilities in the manner of their application, or rather to the defective use of coal, than to any greatly increased calorific value in the fuels themselves.

The object of this paper being simply that of getting the subject out of the mud and on the rails, so that it may, if possible, make progress, the main points alone that were involved have been touched upon, purposely omitting details.

To those who are devoting their efforts in a rational way to the accomplishment of this matter, the points given may be of some value. There are not wanting sanguine inventors who claim that petroleum and its kindred oils have *thirty* times the heating capacity of coal. With these *incurables*, there is not the slightest wish to differ.

NOTE.—As seriously affecting experimental calculations, it may be stated that the specific gravity of petroleum is given in the tables of the most recent standard authorities as .878, which indicates an oil of 30 deg. Baume, and has probably been handed down from old tables, prepared in the time when the only article to be obtained was the brown heavy drippings of the surface rocks. The petroleum of commerce to-day will average 47 deg. Baume, equal to a specific gravity of only .7972, and weighing 49.82 lbs. to the cubic foot.

THE UTILIZATION OF TIDE POWER.

From "Engineering."

It is not unnatural that in a country like our own, dependent to such a large extent for its supremacy upon its mineral wealth, and upon its being able to turn that wealth to account, there should arise from time to time certain mild panics as to the failure of our coal supply and the disastrous results to which that failure is to lead. We are not amongst those who believe that even the present generation are likely to see a time when we shall be short of coal; but our supply is certainly not inexhaustible, and we are quite ready to attach the utmost importance to the diffusion of such knowledge as will check the absolute waste of fuel, which at present goes on to a greater or less extent in nearly every branch of our manufactures. It is for this reason that we by no means deprecate the periodical panics to which we have referred. Such panics do good in many ways. They cause the subject of fuel economy to be discussed at scientific meetings and in the public press, they bring forward schemes for saving fuel which would otherwise remain hidden, and some small percentage of which may possess real value, and lastly, they not unfrequently cause a temporary rise in the price of coal, and in this way compel the attention of many who could be made to regard the matter in no other way. Just at the present time we are having our attention especially directed to the economical use of fuel, by the increased cost due to the general rise of wages, and the excessive demands of our busy iron works and factories, and

hence—as on the occasion of the panics of which we have spoken—we find going on everywhere discussions as to how greater economy is to be obtained, and our supply of coal husbanded. Under these circumstances it appears to us desirable to review briefly our prospects of substituting other sources of power for our combustion of coal.

We all know that work and heat are transmutable, and that every unit of heat developed by the combustion of fuel, or in any other way, represents 772 foot-pounds of work, or *vice versa*. But while we are enabled by the steam engine, and other mechanical contrivances, to transform—but wastefully, it is true—heat into work, and to obtain, by the combustion of our fuel, power for driving our mills and factories, yet we are not possessed at present of any alternative means practically available on a large scale, by which power derived from any other source can be transformed into heat, and rendered available for use in our metallurgical or other processes in which such heat is required. So long as this state of affairs remains, or so long as we are unable to transform work into heat with a fair degree of economy, it is evident that our attempts to economize our coal by deriving power from other sources, can only affect that portion of our expenditure which is incurred in the generation of force or work, and even that but partially, as nowadays a good proportion of the steam used in our iron works is generated by the utilization of what would otherwise be waste heat from the furnaces.

These considerations at once place a very important percentage of our coal expenditure beyond the present chance of being saved by resort to other sources of power, and it remains to be seen what probability there is of these other sources replacing the coal expended in developing force. Here, again, we must at once make some deductions. The portability of coal and its kindred fuels, or, in other words, the facility they afford for carrying an enormous store of power in a small bulk and weight, renders it highly improbable that an efficient substitute will be readily found for them for use under circumstances where the portability is an object, as, for instance, on our locomotives and in our steamships. It is of course quite possible that the time may arrive when our vessels and locomotives may be propelled by other means than steam, or when, if steam is still used, that steam may be generated by other means than the combustion of fuel; but it is not our purpose here to speculate on discoveries which may arise in the future, but to deal with our prospects as they at present stand. At present, then, it seems to us that coal must still continue to be used by us for the direct production of heat, and for generation of power for working our railways and steamers, and the only question that remains is whether any other source of power can be practically turned to account so as to husband the coal—or a portion of it—now expended in generating steam for our stationary engines.

This question has been discussed lately in several quarters, and amongst others, Mr. Bramwell, in his address delivered as president of Section G of the British Association during the meeting of that body at Brighton, has directed special attention to it. As Mr. Bramwell stated, there are three sources of power which have in times gone by been turned to account, namely, that of the wind, that afforded by our streams and rivers, and that to be derived from the flow and ebb of the tides. We agree with Mr. Bramwell in dismissing the first of these sources of power as uncertain, and the second as only being available in special cases, but we cannot agree with him in considering that the utilization of tidal power is quite such a promising matter as he appears to regard it. The enormous power which the tidal waves would be capable of developing, if it were possible to turn it to account, has naturally attracted much attention to the subject, and a number of plans for turning that power to account have been at different times brought forward, both in this country and abroad. So far as we are aware, however, none of these plans have ever been brought into practical use, and we may add that we have, as yet, seen no plan which, if carried out would afford a fair chance of commercial success. We of course know that in certain situations tide mills have been and are, we believe, still being used with more or less satisfactory results; but these mills cannot be included amongst the plans of which we are now speaking, plans which contemplate not merely the collection, as it were, of tide power, but its diffusion to mills and factories situated at considerable distances from the prime motor.

In the address to which we have already

referred, Mr. Bramwell himself proposed a scheme of this kind. The plan which he suggests is that advantage should be taken of the natural configuration of the coast in certain places to form storage reservoirs, from which the water might be discharged at low tide, and made to work turbines, which should in their turn drive pumps, employed in pumping water into hydraulic accumulators. From these accumulators the water, under a high pressure, is to be distributed to the places where it is wanted to drive machinery.

At first sight this appears to be a very plausible idea; but a more careful examination of the features of the case shows that, although plausible, it is by no means promising, except under certain unusually favorable conditions. To explain this it will be as well, in the first place, to show the cost of the power producer with which tide motors will have to compete.

We do not hesitate to say that at the present time no mill engine of any size should be consuming more than 2½ lbs. of coal per horse power per hour. We are quite aware that there are thousands of stationary engines which are consuming more than double this; but this fact does not affect the question, as tide-motors, if they are to be successful, must be able to compete with engines of an economical type.

Again, allowing for holidays and other stoppages, an ordinary mill engine has to run about 2,800 hours per annum, and taking the consumption at 2½ lbs. per horse power per hour, this gives the annual consumption per horse power as $2{,}800 \times 2.5 = 7{,}000$ lbs., or allowing for lighting up, etc., say 3¼ tons. The present price of coal is abnormal, and does not, therefore, form a basis for such calculations as those to which we are now directing attention; and taking into consideration the fact that tide-motors, if successful, would themselves tend to produce a reduction in the price of coal, we think we shall be treating them liberally if we estimate the average cost of the coal with which they would have to compete at 16s. per ton. Taking it at this price, we should have the average cost of fuel per horse power for a really good engine $= 3\frac{1}{4} \times 16 = 56$ shillings, or £2 16s. per annum; or for 1,000 indicated horse power an annual cost for fuel of £2,800. Besides saving fuel, the tide-motor would also render unnecessary the boilers at present employed, and there is, therefore, to be placed to its credit the cost of maintenance of these boilers, the interest of the capital sunk in them, and the stokers' wages. For the 1,000 indicated horse power which we are taking as our example, these items would probably amount in the aggregate to about £800, thus giving say, £2,800 + 800 = £3,600, as about the annual sum which a mill-owner would be justified in paying for a supply of water capable of developing 1,000 horse power during ordinary working hours. The cost of engine superintendence, oiling, etc., and miscellaneous charges, would probably be about the same, whether steam or hydraulic engines were used, and these matters, therefore, need not be considered here.

Let us now examine the other side of the question. The annual charges to which an establishment for utilizing the power of the tides would be subject, would be the interest on the money expended on the works and machinery, the cost of maintenance, and the expenses of superintendence, collection of rates, wages of sluicemen, etc. In the aggregate these charges could scarcely be estimated as amounting to less than 15 per cent. on the capital expended, and in the case of an establishment supplying power in moderate amounts over an extended district it would probably be even more than this. Taking, however, the annual charges as amounting to 15 per cent. on the capital, and taking, also, the yearly rent which might probably be paid for a supply of water capable of developing 1,000 horse-power, as £3,600, we find that the capital which it would be justifiable to expend on tidal works capable of supplying that amount of power would be £24,000, a sum which, we venture to say, would in but excedingly few instances suffice for their execution.

It must be remembered that the expenditure of say £24,000, for each 1,000 horse-power, which the tidal works would be capable of supploying to factories, would have to include not merely the construction of the storage reservoirs, with its sluices, etc., but also the cost of the turbines, pumps, hydraulic accumulators, and last—but by no means least—that of the pipes by which the water under preasure would be conveyed to the works where it could be utilized; and hence, as we have said, we believe that there are very few situations where

the requisite works and plant could be provided for the sum which it would be justifiable to expend.

We have in the present article touched merely upon the general facts bearing upon the supposed economy to be derived from the employment of tidal power; but we have, we trust, shown that the use of that power by no means holds out such promising prospects as its advocates appear to believe. On an early occasion—probably next week—we shall consider the matter in greater detail, and have something to say of the extent and character of the works which would be required to turn tidal power to account.

EXPERIMENTS ON SURFACE FRICTION IN WATER.*

By W. FROUDE, F.R.S.

From "The Mechanics' Magazine."

The object of investigation was to determine the laws which govern this force, in those especial relations under which it forms a portion of the resistance experienced by a ship when moving through the water at various speeds.

These are, (1) the relation of the force to the speed, (2) its relation to the quality of the surface, (3) its relation to the length of the surface along the line of motion. The necessity of investigating it under the latter of these relations may not be at once obvious, it having been generally held that surface friction varies directly as the area surface, and will be the same for a given area whether it be long and narrow or short and broad. But a little reflection shows that this cannot be so, because the portion of surface that goes first in the line of motion, in experiencing resistance from the water, must reciprocally communicate to the water motion in the line in which itself is moving, and consequently, the portion of surface which exceeds the first must be rubbing, not against stationary water, but against water partially moving with it, and cannot experience as much resistance from it.

The experiments were performed with carefully made apparatus, which automatically recorded the resistance and the speed, and the errors and uncertainties of the results probably did not in any case exceed on the whole one-half per cent.

The surfaces used in the experiments were of yellow pine board, about three-sixteenths of an inch thick, loaded at the edge with lead keels of the same thickness, fastened fair and flush with the board, the weights being such as to just neutralize the flotation, and hold the boards stably in a vertical plane. The head end (so to call it) of each board in turn was fastened into a tin sheath, or fine-edged cutwater, which formed a portion of the dynamometric apparatus, and which held the board resolutely in a vertical plane, with its length horizontal, and in the line of motion. The width of each board, including the lead keel, was 19 in., their lengths, including the cutwater, varied from 1 ft. to 50 ft. Great pains were taken, and successfully, to eliminate, and, indeed in effect to obliterate the resistance due to thickness.

It turned out that the effects of the three conditions under which the variations of the force were to be determined, could not be regarded as absolutely independent of each other, because certain variations in the quality of the surfaces were found to affect in some degree the relations of the force to the speed and to the length. The results may be approximately stated in brief, as follows:

1. As regards the relation of resistance to speed. With the surface coated with shellac varnish, Hay's composition, or Peacock's composition, or tallow, the resistance varied very nearly as the power 1.83 of the speed; with the surface quoted with tinfoil, very nearly as the power 2.05 of the speed; but the experiments with the tinfoil are not yet complete.

2. As regards the relation of resistance to quality of surface. With the surface coated with shellac varnish, Hay's composition, Peacock's composition, or tallow, the resistance differed extremely little; such variations as occurred scarcely exceeding one per cent., and being probably not greater than belonged to the small differences of smoothness in the laying on the composition.

* Read at the British Association, Brighton Meeting, Section G, Mechanical Science.

With the surface coated with glue, and thus simulating the sliminess of a living fish, three successive experiments were tried at the same speed, so as to test the effect of the gradual growth of the slimy character. The first experiment showed an increase in resistance of 2 per cent., the last of 4 per cent., as compared with the shellac surface which the glue resembled before immersion, a proof that the attempted imitation of the fish's surface was not advantageous.

Comparing a tinfoiled surface with one coated with shellac, when the length is one foot, the resistance of the former is on the average only two-thirds that of the latter, making the comparison with planes of 1.6 in length, the ratio is three-fourths, and with planes of 16 ft. more then nine-tenths, instead of two-thirds; indeed, the total difference becomes progressively less as the planes compared are longer. At higher speeds also the difference tends to become less, in consequence of the higher power of the speed to which it is proportioned with the tinfoiled surface.

3. As regards the relation of resistance to length of surface. There plainly is a very considerable diminution of average resistance per sq. ft. as the length of surface is increased, and this probably from the course already indicated, though the rate of diminution becomes gradually less as the surface becomes longer; there is, in fact, as great a diminution between 3 ft. and 4 ft. of length as between 30 and 50.

The following tabular statement gives the mean resistance per square foot on surfaces of from 1 ft. to 50 ft. in length, with speeds of from 200 to 800 ft. per minute.

Length of Plane. Feet.	Speed in feet per minute.				
	200	400	600	800	
1	0 048	200	460	·830	Resistance in pounds.
2	·045	188	413	725	
3	·043	183	·390	·673	
5	·042	·166	358	·608	
7	·041	154	·333	·563	
10	·040	145	312	529	
20	·036	·131	·27×	·473	
30	·035	123	·264	·446	
50	·035	·117	·250	·417	

The table is applicable to a clean placed surface coated either with shellac varnish, Hays's or Peacock's composition, or tallow.

ELECTRO SCIENCE, AS A PART OF THE EDUCATION OF CIVIL ENGINEERS.*

There are few subjects with which, in a general way, the mass of the people are better acquainted than that of electricity.

Nearly every schoolboy passes through a period when his whole soul is absorbed in the preparation of glass bottles and Leyden jars; often maternal patience is tried to its utmost extent in the discovery of dilapidated tablecloths and varied colored garments, sacrificed in the interest of juvenile research in the school of Voltaic science.

Merchants, manufacturers and brokers are becoming more than amateur telegraphers, and in every department of industry, electricity is being used as a practical agent, and practical results are obtained. Yet there is no science of which so little is understood by practically scientific men.

I propose, therefore, to submit for consideration some of the reasons which seem to me to account for the apathy of that class of men in making exhaustive research, or even to exhibit general interest in an element already largely ultilized by application in almost every known art, and assuredly destined at an early day to hold a position of still greater magnitude and importance.

For many years, known only in the phenomena exhibited in the chambers of natural philosophy and of educational institutions, the subject of electricity was regarded, not as one of special or practical utility, but simply of such slight interest as might belong to the contemplation of any natural phenomena, and one of which no man of education and culture should be entirely ignorant.

Its first application to an important and useful art was to that of telegraphy, and so limited then in this field were the resources of scientific men that the application of electro-magnetism to the purposes of distinct intercommunication was, and still continues to be regarded as an entirely new and original discovery.

* A paper read by STEPHEN CHESTER, Civil Engineer, Member of the American Society of Civil Engineers.

We observe here that the application of electricity in this instance was not to accomplish more than a special and limited result, through the special and limited means of repeated electro-magnetic impulses. The problem to be solved was simply the production of controllable and recognizable signals at a distance. This accomplished, questions of economy, and expedient means of producing the element upon which these results depended were for after consideration, and were naturally esteemed of relatively insignificant importance.

The rapidly increasing demand for quick communication between distant places soon made electro telegraphy one of the most important business enterprises of the country, and under this stimulus lines sprang up in all parts of the United States and of the world; armies of employees soon became trained and skilful experts in the practice, and indeed in the general knowledge of the subject, so far as producing the special and limited results required in this specific application.

Hence, specific experimental knowledge of electricity as an applied science, has been almost exclusively confined to a class of men, who, however bright and intelligent they may have been, were nevertheless entirely unqualified to develop largely any important and valuable result from their relatively wide experience, because:—first, they came almost wholly from a class of society early thrown into active employment with but an ordinary school education; second, no antecedents of employment or training had prepared them in capacity or disposition for the habits of exhaustive analysis required to develop a new science; and lastly, their field of observation and experiment has always been limited to the accomplishment of a specific result.

In later years, the many new and useful applications of electricity in arts, other than electro telegraphy, has stimulated the competitive efforts of manufacturers to further and more important applications. Under this stimulus, the attention of the scientific world has of late been drawn more directly to the subject, and men like Seimm, Clark, Becquerel, Sabine, Dumoncel and others, have made valuable additions to general science in elaborate works upon electricity.

But these are for the most part "men of the schools," and while their books evince patient study and careful analysis, the character of our standard works is not such as we would expect and require from men who, from previous training and long habits of practically applying abstruse theorems to actual construction and problems to be solved, would naturally investigate this subject rather in its application to specific results, than in its general connection with abstract science.

Again growing out of the antecedents that I have mentioned, is a popular and widely different error, that this is not a positive science (if I may use the expression in this connection); that all knowledge of the laws governing this subject must of necessity be vague, uncertain, and beyond the limits of mathematical measurement and calculation; and that this mysterious invisible element is recognizable only in, and through, the phenomena attending its vibrations and movements, and by which then the experienced expert may judge of the presence of the unseen agent, with about as great a degree of certainty as the physician forms his diagnosis of disease from the varying symptoms of his patient.

On the contrary, notwithstanding the fact that our researches in this direction have been hitherto desultory, and far from exhaustive in their nature, and our acquaintance with the laws governing the operations of electricity are very limited,—yet we have developed this fact with great certainty, that it is no uncertain science, but one susceptible of exact analysis conforming to arbitrary, positive rules and calculation. This invisible, silent and mysterious force can be measured in its length, breadth, and thickness, with the accuracy that the beam of a truss may be measured; the consumption of material required to develop it in known and determinable qualities, may be as closely estimated as the effective working amount of steam can be computed from the amount of coal burned; and the electro motive effect of this force under any given conditions, may be as exactly calculated as that of the thrust of a brace under given conditions. I do not say that this has also been literally accomplished; but such advances have been made, that the ultimate result is no longer a matter even of probability.

Already European governments have made this subject one of the principal studies in the course of military education. In this country, our military and naval schools

have included in the courses, with instructions of a general character, the application of electricity to specific offensive and defensive objects, and we have both in the army and navy, schools for teaching in torpedo and signal service. It is not necessary, if the time would now permit, to point out how inadequate such instruction must be, except so far as to accomplish the specific limited object in view.

To the civil engineers of the country, men peculiarly fitted to the task by reason of special training and experiences, *mechanics* rather than chemists, philosophers and abstract scientists, belongs the duty of developing this subject to the dignity of a practical science.

As my time is nearly exhausted, let me add one reason why this subject should be intrusted to the hands of practical engineers, and not only to philosophers and students of abstruse science—*the public welfare demands it.*

Under cover of our general American apathy, to which I have before alluded, the popular impression has been largely cultivated, that this is a vague, uncertain, eccentric power, its laws unknown and undiscoverable, and that the simple manipulations of telegraphy could be acquired only by special experts; and more by reason of this popular ignorance, than from any other cause, extensive telegraphic monopolies have been built up to which we are paying a profit of 400 per cent. for every message we send by them.

Lastly, let me remark to the body of men before me who have attained individually to reputations of which the country may well be proud, and collectively to an eminence second to that of no similar body in the world, I cannot but think it a burning shame that the greatest, richest, and politically the most powerful telegraph company in America, if not in the world, should, from necessity, if not from a less reputable reason, have been induced to secure the services of an English expert to instruct operators in the first principles of their own especial calling.

It is hardly to be doubted for a moment that this science, entering as it already does, and will through so many devices, into the manipulations of many useful arts, will, in the future, form an indispensable part of the education of civil engineers. In our own time and generation we may anticipate this inevitable result.

Mr. Collingwood: Will Mr. Chester state some of the important effects of electricity? It is used, I am sure, in the arts, beyond what any of us knows.

Mr. Chester: I presume it would be a very interesting subject, if time permitted, but it is one that requires some degree of preparation to present to the Society in an instructive form.

I will say that, generally, it is used with different devices for controlling automatic machinery—controlling it in the sense that the brain and nerves may control the muscular system; not as a positive force, but as that which governs a positive force. There is hardly a limit to the number of applications which might be devised, for applying electricity in this way, in the several branches of manufacturing art.

Mr. Coryell: Cannot electricity or galvanism be brought to bear in testing the strength of iron and steel? Will not the arrangement of the light and the position of the rays assist in determining the quality of iron and steel?

Mr. Chester: Experiments of this kind have been made. The capacity for conducting electricity is an almost positive test of the purity of copper. The same test, or a test of a similar nature, may be applied with very exact results to iron. Experiments have been made, I understand (I do not know how far they have been carried beyond the limit of my own experience), in testing the quality of iron by magnetic impulses.

ON ECONMY OF FUEL AND PREVENTION OF SMOKE.

By CAPTAIN J. GORDON McDAKIN.

From the "Journal of the Society of Arts."

The heating surface being in proportion to the result required, there is still in all furnaces, and particularly in those of marine engines, a loss amounting to at least 25 per cent., arising from imperfect combustion. Indeed it has recently been stated, on the authority of a Royal Commission, that our best Cornish engines only utilize one-eighth

of the coals burnt, and the majority of engines not more than one-thirteenth.

In order that I may explain the object that I have in view, and the principle of my system, by which I seek to prevent this loss, it is necessary to consider the nature of those effects which we find in operation in the furnaces of our engines.

When coal is burnt in the open or in the ordinary house grate, the principal products of combustion are carbonic acid and water; a certain portion of finely divided carbon escapes combustion and constitutes the soot or visible smoke of a coal fire. When the decomposition of coal is effected in retorts or vessels from which the air is excluded, the products are much more numerous and complicated. A large amount of volatile matter is expelled, partly in the form of hydrocarbon gases, and partly in the form of hydrocarbons in the state of vapor, solid coke remaining in the retort.

Now, different parts of the furnace frequently represent the conditions of the open fire and retort, also constantly varying in place and temperature. In the laboratory if we want a smokeless gas flame, we adopt some contrivance similar to the Bunsen's burner, in which a mixture of air and gas takes place (as in some varieties) through wire gauze, the particulars of air and gas being thoroughly distributed through the entire volume; the molecules of each gas coming into individual contact, a condition that is essential, and the result is a smokeless flame, in which glass tubes and white porcelain capsules may be heated without becoming blackened.

This would not be the case with the ordinary gas-jet burning in the open; the supply of air in this is abundant, but it is not commingled with the flame, only coming into contact with the outer shell, producing a flame that deposits a thick soot on any other object placed in it, pointing out the absolute necessity of maintaining the conditions of combustion that we possess in the Bunsen's burner.

It would be simply ridiculous to attempt to make gunpowder by the hap-hazard throwing together of saltpetre, sulphur, and charcoal. The proportions of the gun and projectile might be the best, but what result should we have from an explosive so prepared? It is doubtful whether it would ever burn. Is there not a close analogy between this and the well-constructed boiler and furnace, and the condition of the combustible material represented in the latter by the imperfect mixture of air and flame? Not only may vast quantities of unconsumed carbon pass off in a dense smoke, but also volumes of invisible and inflammable gases escape ignition, as they would from the retort of a gas factory, and at a low temperature the furnace may actually be distilling hydrocarbon oils, as in one specially built for that purpose.

It is this visible loss in smoke, and visible loss in unconsumed gases and vapors, which it is our object to save by the proper admixture of the atmospheric oxygen.

Various contrivances have been proposed for this purpose, and adopted with more or less success. Improvements at the bottom of the furnace, as in the ventilating fire bars, which make a better distribution of the air, at the lower part of the fuel. In others the air has been admitted at the fire-door, and at the back of the bridge; but the volume of air has generally been greater than necessary, chilling the gases below the point of ignition, the stream of cold air only coming into surface contact with the heated gases, as some ocean currents of hot and cold water are said to flow side by side without mingling with each other.

It is, therefore, the thorough admixture of the heated gases with air, as in the Bunsen's burner, which is the essential feature of the system which is the subject of this paper.

The object in view I seek to attain as follows:—

In each tube of an ordinary tubular boiler is inserted another of much smaller diameter, perforated at its end nearest the fire in such a manner as to cause an induced draught when required, by a current of air flowing through the said tube, or being forced through by a blower or steam jet, this being under perfect control by opening or closing a valve. Each of the boiler tubes is in this manner filled by a smokeless flame of great intensity—the deposit of soot and dust is reduced to a minimum, there not being any smoke except on first lighting the fires. No obstruction is offered to cleansing the tubes, and the inner ones can be separately unscrewed, or removed in sets, when it is required to prick out the perforations or to renew the ends.

The expense is small, the air pipes costing not more than a few pence per foot, and no alteration for their introduction being required except of a most trifling nature.

The same system is applicable to locomotives and other engines.

LOADS AND DEFLECTIONS OF SOLID BEAMS.*

From "The Builder."

The methods which have been in use for the last twenty years for calculating the strength of iron beams, have all been more or less based on the experiments and mathematical investigations made by the late Eaton Hodgkinson; and the author of the essay before us has not been able to discover anything more reliable than the recorded results obtained by that eminent experimenter; the chief novelty about his investigations consisting in the view he takes of those results in their bearing upon the strength of beams. He finds fault with the usual methods of calculation, because they give the breaking or ultimate strength instead of what is really wanted by the practical engineer, the proof strength or the utmost load that can be put upon a beam without permanently injuring its elasticity.

In cast-iron beams, Mr. Donaldson considers that experiments show that the modulus of elasticity whether for tension or compression, can be taken as nearly the same, when the load is not sufficient to impair the elasticity of the material; but that in beams of wrought-iron the modulus for extension is to that for compression in the proportion of 14 to 11.

Mr. Donaldson's investigations differ therefore in this point from previous ones, in taking two moduli—one for compression, and another for extension—instead of an average modulus to include both strains. This is no doubt the correct method, but it involves more complicated formulas, and it may well be questioned whether such nicety is of much practical value in determining the strength of beams, since we seldom find that any two specimens have exactly the same modulus, and therefore, after all, only an average value can be taken.

There is one other important point in which our author differs from his predecessors, which consists in taking the ratio of tensile and compressive stresses as widely different when proof stress or ultimate stress is under consideration. The ultimate compressive strength of cast iron, as determined by experiments on short cylinders, is about six times the ultimate tensile strength; and on this relation the form of section of what is called the Hodgkinson cast-iron beam is based, making the metal of the bottom flange, which suffers a tensile strain six times that of the upper one which is under compression. Mr. Donaldson, however, considers that this is a wrong conclusion to draw, and that the *proof* compressive strength being only three times the *proof* tensile strength, the form of the girder should be based on this principle, and not on the ultimate or breaking strength of the metal. He takes this view of the relations of proof and ultimate stress from a table of experiments given by Hodgkinson, in the Parliamentary Report for 1849, which were made on a number of cast-iron rods 10 ft. long and 1 in. sq., in which it appears that a compressive force of 25,600 lbs. was all that they would bear without injury, the tensile strain being 8,000 lbs., without impairing the elasticity. If we refer, however, to the record of these experiments, we find it stated that the rods were enclosed in an iron frame, which prevented their getting out of a right line; but, notwitstanding this precaution, some of the bars strained with 16 or 18 tons had become very perceptibly undulated. This might well be expected from their great length, as compared with the width, which would be of no consequence in tensile strain; but when a compressive force was applied, the resistance would vary according to the ratio of breadth to length, the strength of very long pillars being shown by Hodgkinson's other experiments to be nearly inversely as the square of the length. It appears, therefore, that the experiments which Mr. Donaldson quotes are not of much value for the purpose of determining the resistance of the upper flange of loaded beams to compression, and that a proof stress for compression of one-fourth the ultimate strength is far too little to allow in beams of cast-iron.

With regard to wrought-iron, it is almost impossible to fix with any accuracy the average ultimate strength, whether compressive or tensile, since so very much depends on the quality and ductility of the metal, there being no exact point in good wrought-iron at which crushing can be

* New Formulas for the Loads and Deflections of Solid Beams and Girders. By W. Donaldson, M. A. New York: Van Nostrand. 1872.

said to occur; while, on the other hand, it may generally be drawn out very considerably by a tensile force before fracture takes place. Mr. Donaldson takes as his authority some experiments of Hodgkinson's on bars 10 ft. long by 1 in. sq., and from these he deduces the ratio of 3 to 2 as that of proof compressive to proof tensile stress in wrought iron. This, however, is an inference drawn from one set of experiments only, and very different results are shown by Hodgkinson in another set, on bars of larger diameter. In subjecting long bars of wrought iron to a compressive force in the direction of their length, although kept from bending by mechanical means, the same difficulty will arise as mentioned in the case of those of cast iron, and they can only be considered as long pillars, whose strength depends on the ratio of diameter to length. For these reasons, we can hardly admit that Mr. Donaldson has proved the principle which he affirms, "that it would be wrong to use formulas with constants determined by ascertaining the experimental breaking-weights, to design beams intended to support proof and working loads."

But whatever difference of opinion there may be as to the conclusions to be drawn from experiments, there can be none as to those deduced by pure mathematical reasoning, in which Mr. Donaldson is certainly an adept, and has worked out, by means of the integral calculus, very exact formulas for finding the strength and deflection of beams in cast or wrought iron and timber. These formulas are quite independent of the results of experiments, and will be found of equal use whatever value of constants the engineer may deem it advisable to employ. It will only be those who have a good acquaintance with algebra that will be able to follow the author's arguments or to understand the application of the formulas deduced; but the following are some of the results obtained, and which will not be difficult of practical application.

In the case of solid rectangular beams of any material, let W be the load applied at the centre of the beam, w the weight per unit of length (l) of the beam itself, d the depth and b the breadth of the beam, f, f'' the horizontal components of the stress per unit of area on the extreme bottom and top edges respectively actually exerted, E the modulus of elasticity in extension, E' the modulus in compression; then the relation between the applied forces and the resistances is expressed by the equations—

$$W + \frac{l\,w}{2} = \frac{4fd^2b}{3l\left(1+\sqrt{\frac{E}{E'}}\right)}$$

or,

$$= \frac{4f''d^2b}{3l\left(1+\sqrt{\frac{E'}{E}}\right)}$$

the upper or lower expression to be used according as E is less or greater than E'.

The deflection at the centre of a rectangular beam with a distributed load is,

$$\text{Deflection} = \frac{5f\left(1+\sqrt{\frac{E}{E'}}\right)l^2}{48Ed}$$

or,

$$= \frac{5f\left(1+\sqrt{\frac{E'}{E}}\right)l^2}{48E'd}$$

The deflection produced by a central load is to that by a distributed one of equal amount in the proportion of 8 to 5.

In the case of flanged girders, let D be the distance between the centres of gravity of the top and bottom flanges, A and A' their sectional areas; then we have the relation between the forces determined by the equations,

$$W + \frac{l\,w}{2} = 4fA.D$$

or,

$$= 4f'A'.D$$

If the areas of the flanges are proportioned so that

$$\frac{f}{f'} = \frac{E}{E'}$$

then the central deflection, with a central load, when f is constant, is,

$$\text{Deflection} = \frac{fl^2}{4Ed},$$

or,

$$= \frac{f'l^2}{4E'd}$$

Mr. Donaldson has also devoted a few pages of his essay to the investigation of the ratio of depth to span in wrought-iron railway girders, for which a table is given with the ratios varying according to the spans.

THE GENERATION OF HEAT DURING THE BESSEMER PROCESS.*

By RICH AKERMAN, Professor at the School of Mines, Stockholm.

From "Engineering."

Experience has more and more confirmed that, having at hand proper materials for the Bessemer process, there is nothing which exercises so powerful an influence on the quality of the product as the degree of heat which is attained during the process. The greater this heat the closer and more homogeneous will, as a rule, the Bessemer metal turn out, besides which the danger of its becoming red short is proportionately diminished; nor does it seem improbable that the brittleness, which at times characterizes Bessemer metal, stands in some relation to a deficiency of heat during the process. Lastly, a good heat will also produce a larger percentage of steel in ingots, partly because a less quantity of material is thrown out by the blast, in proportion as, by the raised temperature, the bath is rendered more liquid, and partly because the metal refined at a high temperature is sufficiently superheated not to cool in tapping and thus to form scull. A correct insight into all the circumstances which during the process in question affect the degree of heat must therefore be of the greatest importance to every Bessemer smelter; the more so that the differences between the kinds of pig iron employed in Bessemer steel making, which arise from the varying qualities of the ores, are sufficiently marked to require very different conditions in different places to attain the desired high temperature.

The wish to contribute, at least in some slight degree, to a dissemination of the knowledge, in these respects, which has hitherto been acquired, is the principal motive for the present memoire, which has, however, been more immediately called forth by two dissertations published in the course of last year, namely, Mr. Jordan's, in "Bulletin de la Société des Ingenieurs Civils," and Professor Kupelwieser's, in "Oesterreichische Zeitshrift für Berg- und Hütten-wesen," from which papers the substance more essentially bearing on Swedish production will be communicated in the following, conjointly with my own calculations and views.

The object of conversion, as is well known, is to free the iron from the matters with which it is combined in the pig, and which principally consist of carbon (from 2 per cent. to 5 per cent.), silicon (0.1 to about 1.3 per cent. in Sweden, but from 0.3 up to 4 or 5 per cent. in coke pig iron), and manganese (from traces to about 4 per cent., and in spiegel iron occasionally as much as 20 per cent.) The removal of these matters is brought about by their oxidation, which does not, however take place quite simultaneously, for at the commencement it is, principally at least, the silicon and maganese, together with a small portion of iron, which are oxidized, while in ordinary cases most of the carbon is only removed after the greater part of the two first-mentioned substances has formed a slag.* The silicon and manganese remain, even after oxidation, in contact with the iron, forming as silica and protoxide of manganese, together with the oxidized iron, slag; but the oxidized carbon, on the other hand, goes off partly as carbonic oxide, which afterwards, in contact with the air, is further oxidized into carbonic acid.

Conversion by smelting was, up to the year 1855, exclusively effected by the pig-iron—either in contact with charcoal, as in the hearth-forging, or separated from the fuel as in puddling—being smelted down and exposed to the oxidizing influence of the air, as well as of the slag, and in this process no consideration whatever was attached to the generation and consumption of heat which was caused by the chemical reaction taking place in the smelted mass; but in order to obtain a sufficient degree of heat, the simple expedient was adopted of burning separate fuel. The heat engendered by the combustion of this fuel was, however, in by far the greater proportion, entirely lost, partly with the dispersing products of combustion, and partly by the outward radiation from the walls of the furnace, whilst only an inconsiderable portion was brought to act on the iron, partly by its

* Translated from the Minutes of the Institution of Civil Engineers in Sweden, by C. P. Sandberg.

* See Calvert and Johnson's investigations of the puddling process, "Annals of the Iron Office," Stockholm, 1858, page 202; Kollberg on the Bessemer process, "Annals of the Iron Office," 1865, page 314, and Brusewitz on the same subject "Annals of the Iron Office," Stockholm, 1871, page 222.

contact with the flame, and partly by the heat communicated to the mass from the furnace walls. In order by this method to smelt down 2 tons of pig iron in a puddling furnace, and heat it to about 1,400 deg. Centigrade, a quantity of about 1 ton of coal was consumed, from which was produced about 7,500,000 calories*; but of these, according to Jordan, 5,000,000 to 6,000,000 were carried away with the gases, and about 1,000,000 were lost by radiation from the furnace walls, while only about 600,000 calories, or say, $\frac{1}{13}$ of the heat produced, were absorbed by the pig-iron bath. Now, as regards the fuel which is consumed in the puddling, as well as the charcoal hearth process, after the pig iron is smelted, the said fuel is not only entirely wasted by these processes, but a proportion of the heat produced by the oxidation of silicon, manganese, iron and carbon, which takes place during these processes is, in point of fact, lost also. The correctness of this asssertion will be best apprehended by a comparison with the Bessemer process, in which, with the exception of that possibly necessary for smelting down the pig-iron, no separate expenditure of fuel is required; but the heat generated by that process in itself is so well made use of, that the material or metal remains in a liquid state, and is consequently much more heated than during the puddling process or process of refining in the hearth.

The Bessemer process consists, as is well known, in forcing atmospheric air through the molten mass of pig iron, and the cause why the heat generated by this process is so much more completely utilized than in the other converting methods, is simply from the briskness with which the conversion takes place in the Bessemer converter, the whole mass being penetrated by compressed air, and the refining, or oxidation, being consequently effected simultaneously through the whole mass. This "intermolecular" combustion pervading the whole mass of iron, is also the cause of the walls of the Bessemer converter not becoming so superheated as would be the case if it were attempted to bring the mass up to a similar degree of temperature in a reverberatory furnace, because the walls of the Bessemer converter receive the heat, so to say, second-hand from the metal, whereas the contrary takes place in a reverberatory furnace, in which the metal is heated chiefly by the radiation from the roof and walls. It is clear, moreover, that the greater the mass which is manipulated at one time and the more quickly the process is carried on, the less is the proportionate heat which the walls of a Bessemer converter will have time to absorb and conduct away, and the hotter, in consequence, will be the metal.

Following, principally, Mr. Jordan, we will now, in the first instance, endeavor to explain the conditions of heat which take place during the oxidation of the different substances which enter into the composition of pig iron, as well with pure oxygen as with atmospheric air, and with so-called "dry" steam at a temperature of 100 deg. C.; but before doing this it will first of all be necessary to put forward certain assumptions in respect of the condition of the pig iron bath, etc.

According to Pouillet and Péclet, the melting temperature for white pig iron, rich in carbon, is 1,054 deg. C., and for grey pig iron, rich in graphite, 1,200 deg. C. According to L. Rinman, the smelting temperature for ordinary Swedish pig iron stands at about 1,200 deg. C. Its heat of liquefaction, by the same authority,* amounts to 46 calories, and its specific heat

between 0 deg. C. and 200 deg. C. to	0.13
" 0 deg. C. and 1200 deg. C. to	0.16
and for molten pig iron to	0.21

If, therefore, the initial temperature of the Bessemer pig iron bath is assumed to be 1,400 deg. C., or 200 deg. higher than necessary for melting the pig iron, it would for each ton of pig iron possess:

$$1000\ \{(1200 \times 0.16)+46+(200 \times 0.21)\} = 280{,}000$$

calories, and to change its temperature 1 deg. C. would require the addition or subtraction of 210 calories for the same quantity.

It will be shown, further on in this memoire, that the whole of the oxygen contained in the current of gas injected for converting the pig iron is not always completely absorbed by that pig iron, but that this only takes place under certain conditions; but inasmuch as it should always be the object to try to bring about a complete utilization of the oxygen (because otherwise the metal will become less heated), we will

* A calorie =3.968 British thermal units.

* Survey of the Transactions of the Royal Academy of Sciences, 1865.

in the following calculations uniformly assume that the oxygen has been fully utilized. It may further be presupposed that the gases passing off from the bath have, in ascending through the latter, absorbed so much heat that, in the main, they leave the bath with its initial temperature, or 1,400 deg. Finally, we will likewise assume that the walls of the converter are perfectly infusible, and that no heat is carried away through them from the bath. These assumptions certainly can never be fully realized, but no essential discrepancies need occur on account of them, inasmuch as this desideratum is approached nearer and nearer in proportion as larger quantities of pig iron are converted at the same time, while the process, nevertheless, is accelerated.

In order to make the calculations as easily applicable as possible, they will throughout be made per ton of pig iron.*

COMBUSTION OF IRON.

1. *With Oxygen.*—For the oxidation or combustion of 10 kilos. of iron, or 1 per cent of the assumed quantity of pig iron there will be required, 8 : 28=2.857 kilos. of oxygen and the product is 12.857 kilos. of protoxide of iron, in the formation of $2.857 \times 4{,}205\dagger = 12{,}013$ calories are produced.

The whole of this heat cannot, however, be utilized by the iron bath, partly because the protoxide which has been formed decreases the quantity of the metal, and partly because it has a higher specific heat than the metallic iron (0.17 instead of 0.11 in the solid, and probably still more in the molten state) on which account it must deprive the bath of at least

$$\{12{,}857 \times (0.17 - 0.11)\}1400 = 1520$$

calories.

There remain consequently for the additional heating of the bath, per ton pig iron employed, 12,013 — 1,520=10,493 calories for every per cent. of iron burnt with oxygen gas.

2. *With Atmospheric Air.*—For the combustion of 10 kilos. of iron will be required 2.857 kilos. of oxygen, which in the air is accompanied by $\frac{2.857 \times 77}{23} = 9.57$ kilos. of nitrogen. The quantity of heat generated in a ton of pig iron would, as in the previous case, amount to 10,493 calories, were it not that the nitrogen, in ascending through the bath, absorbs and carries away with it $9.57 \times 0.244 \times 1{,}400 = 3{,}269$ calories. In this case there will consequently be 10,493 —3,269=7,224 calories which, in every per cent. of oxidized iron per ton of pig iron, can be utilized for the bath.

3. *With Steam.*—For the combustion of 10 kilos. of iron 2,857 kilos. of oxygen is required and consequently $2.857 \times 9 : 8 = 3.214$ kilos. of steam, which contains 0.357 kilos. of hydrogen. The quantity of heat generated by the combustion of 10 kilos. of iron amounts, as in the foregoing cases, to 10,493 calories; but if the injected steam has a temperature of 100 deg. C., the amount of heat thus introduced must be added, which makes $3.214 \times 0.475 \times 100 = 153$ calories, so that the whole quantity of heat generated per ton of pig iron by the oxidation of 1 per cent. of the iron in this case amounts to 10,493+153=10,646 calories.

On the other hand, there will be required for the decomposition of the steam $0.357 \times 29{,}638 = 10{,}581$ calories, and if the hydrogen set free in the process should escape at a temperature of 1,400 deg., and its specific heat were 3.40, it would carry away from the bath $0.357 \times 340 \times 1{,}400 = 1{,}699$ calories. The total consumption of heat would, therefore, be 10,581+1699=12,280 calories. For every per cent. of iron oxidized by means of steam there would consequently be a decrease of heat per ton of pig iron equal to 12,280—10,646=1634 calories.

This diminution of heat, caused by the oxidation of iron with water, cannot in reality, however, be quite so considerable, for in the first place the hydrogen, in passing off, cannot carry so high a temperature as 1,400 deg., because in this case the initial temperature of the bath is not increased, but is, on the contrary, reduced; and in the second place it cannot, for reasons which will hereafter be more fully explained, be correct to set down the specific heat of the hydrogen as high as 3.40, inasmuch as this figure represents its specific heat under constant pressure, while its specific heat, at a constant volume, is only 0.2356. Some intermediate value between these two figures would therefore be the right one in this case, but it is difficult to define it, depending, as as it does, on the pressure of the gas in the flue of the furnace, or in the aperture for the escape of the gases from the converter.

* 1,000 kilos are taken as equal to 1 ton.
† Jernkonteret's Annaler, Stockholm, 1871, p. 102.

Now if the quantity of heat carried away by the hydrogen is computed on the assumptions that the specific heat is only 0.236, and that the hydrogen, when escaping, has only a temperature of 800 deg., the loss of heat here in question would be limited to $0.357 \times 0.236 \times 800 = 67$ calories, and the total consumption of heat would amount to $10,581 + 67 = 10,648$ calories, which at any rate does not fall short of the generation of heat (10,646 calories); from which it is evident that in the combustion of iron with steam a reduction of heat must always take place.

COMBUSTION OF MANGANESE.

The calorific effect of manganese, as far as the author is aware, is as yet unknown; but inasmuch as its equivalent weight not only scarcely differs from that of iron, but also the specific heat of the oxide of manganese very nearly coincides with that of the oxide of iron, it is assumed by Mr. Jordan that the calorimetrical heating effects of these substances must correspond pretty closely. The specific heat of manganese is, however, higher than that of iron, and the protoxide of manganese, in particular, is a good deal more difficult to reduce than the protoxide of iron, and it seems, therefore, on these grounds, to be not altogether unreasonable to assume that the calorific effect of manganese is considerably higher than that of iron. The strongest support for this theory is, however, afforded by the great development of heat which generally distinguishes the treatment, according to the Bessemer method, of such kinds of pig iron as contain any appreciable admixture of manganese; but until the calorific effect of manganese shall have been ascertained by direct experiments, there can, naturally, be no question of calculations as to the quantity of heat generated by the oxidation of that substance.

COMBUSTION OF CARBON.

1. *With Oxygen.*—To convert into carbonic oxide 10 kilos of carbon or 1 per cent. of the quantity of pig iron taken as a normal, will require $\frac{10 \times 8}{6} = 13.33$ kilos. of oxygen gas. Whether this combustion is effected directly or by indirect action, that is to say, by the oxidation of iron and the reduction again of this iron through the carbon, its result ought, under ordinary circumstances, when combustion, as in the Bessemer process, takes place in a bath of molten iron, to consist in carbonic oxide, for the carbonic acid which may possibly have been formed must be assumed to have been instantly reduced by the molten iron* under the influence of a temperature very highly elevated. Reasons are, therefore, in all probability, not wanting for supposing that the quantity of heat generated by the combustion of the carbon contained in the pig iron is in any case equal to the amount of heat generated by the combustion of carbon into carbonic oxide. By the combustion in question there ought, consequently, under ordinary circumstances, to be formed 23.33 kilos. of carbonic oxide, resulting in the generation of 24,730 calories.

If the carbonic oxide, when escaping, possesses a temperature of 1400 deg., it will, however, deprive the bath of $\{23.33 \times (0.2479 - 0.241)\} \quad 1400 = 4718$ calories, and there will, consequently, remain $24,730 - 4718 = 20,012$ calories per ton of pig iron, for every hundredth part of carbon burnt with pure oxygen, available for the further heating of the metal.

2. *With Atmospheric Air.*—In order to convert 10 kilos. of carbon into carbonic oxide, there is required 13.33 kilos. of oxygen, which, in the atmospheric air, is intermixed with $13.33 \times 77.23 = 44.66$ kilos. of nitrogen.

The quantity of heat generated by this combustion amounts, as in the case last mentioned, to 24,730 calories, but of these 4718 calories are carried away with the carbonic oxide which has been formed, and $44.66 \times 0.244 \times 1400 = 15,260$ calories with the nitrogen, so that there only remains for the heating of the bath per ton of pig iron $24,730 - (4718 + 15,260)$† $= 4752$

* It has been now long known that the combustion of iron can be effected by means of carbonic acid and that this faculty of iron to reduce carbonic acid, increases with the degree of heat; but Mr. Bell, in his paper on "Chemical Phenomena of the Iron Smelting" published in the "Journal of the Iron and Steel Institute, 1871," has also shown that this reaction increases more rapidly with the elevation of temperature than the opposite one, or the reduction of oxidized iron by carbonic oxide, and that a jet of carbonic acid, passed over iron sponge at about 400 deg. was so completely transformed into carbonic oxide, that after contact with this iron, the gas consisted of 96 vol. per cent. of carbonic oxide and 4 vol. per cent. of carbonic acid.

† Neither in this nor in any of the other calculations has any account been taken of the modification caused by the carbonic oxide, as well as the nitrogen, having a greater pressure in the Bessemer furnace than in the surrounding atmosphere. Instead of the specific heat of the carbonic oxide and the nitrogen at constant pressure being respectively 0.2479 and 0.2440, they are, at constant volume, 0.2399 and 0.237, and the quantities of heat carried away by the gases would, with these values attached to their specific heat, be $\{(23.33 \times 0.2399 - 0.24)\} \; 1400 + (44.667 \times 0.237 \times 1400) = 4462 \times 14,828 - 19,290$ calories. Adopting this opposite extreme, there would remain for heating the bath per ton of pig iron $24,730 - 19,290 = 5440$ calories for every per cent. of carbon oxidized with atmospheric air.

calories for every per cent. of carbon which has been oxidized by means of atmospheric air.

3. *With Steam.*—To convert 10 kilos. of carbon into carbonic oxide 13.33 kilos. of oxygen are required, to produce which it will take 15 kilos. of steam, containing, besides the oxygen, 1.667 kilos. of hydrogen. To decompose this quantity of steam $1.667 \times 29.638 = 49,407$ calories are absorbed, and if the hydrogen entered at 100 deg., and passed away at 1400 deg., it would have deprived the bath of $1.667 \times 3.4 \times 1300 = 7367$ calories, so that the total consumption of heat amounts to $40,407 + 7367 = 56,774$ calories.

The generation of heat, on the other hand, amounts to the same as when the carbon is oxidized with pure oxygen, or $24,730 - 4718 = 20,012$ calories, to which, in this case, must be added, however, the quantity of heat introduced with the oxygen, consisting of $13.33 \times 0.218 \times 100 = 290$ calories, so that the total generation of heat amounts to $20,012 + 29 = 20,302$ calories. The quantity of heat taken away from the bath for every per cent. of carbon per ton of pig iron oxidized by steam would, therefore, amount to $56,774 - 20,302 = 36,472$ calories.

Were it practicable to estimate correctly the loss in specific heat sustained by the the gases in consequence of their condensation, a much reduced value would, no doubt, be arrived at for the decrease of heat in question when narrow funnel apertures are employed; but a comparison with the calculations made in this respect, as will be shown hereafter, will easily indicate that, even if the specific heat of hydrogen were only estimated at 0.2356, and that of carbonic oxide at 0.2399, the combustion of carbon with steam would nevertheless bring about so great a reduction in temperature that the iron could not be kept in a liquid state without an extraneous accession of heat.

COMBUSTION OF SILICON.

1. *With Oxygen Gas.*—For the combustion of 10 kilos. of silicon, or 1 per cent. of the assumed weight of pig iron, $24 : 21 = 11.429$ kilos. of oxygen are required.

By this combustion 78,300* calories are produced, but a portion of this heat is consumed in heating the silica which has been formed to a temperature equal to that of the bath. To be able to state how much heat is absorbed for this purpose, it would be necessary to know the difference in specific heat between silica and silicon; but until this difference becomes known it must suffice to assume the amount of heat in question to be equal to that which is required to raise the temperature of the injected oxygen gas to 1,400 deg., or $11.429 \times 0.218 \times 1,400 = 3,488$ calories. There remains consequently in this case, per ton of pig iron, for heating the bath, the enormous quantity of $78,300 - 3,488 = 74,812$ calories for every per cent. of silicon oxidized with pure oxygen gas.

2. *With Atmospheric Air.*—For the combustion of 10 kilos. of silicon 11.429 kilos. of oxygen are required, which in atmospheric air is intermixed with $11.429 \times 77 : 23 = 38.261$ lbs. of nitrogen, which in escaping deprives the bath of $38.261 \times 0.244 \times 1,400 = 13,070$ calories.

During this combustion there are, as in the foregoing case, 74,812 calories produced, and for every per cent. of silicon oxidized with atmospheric air the amount of heat in the bath is consequently increased, per ton of pig iron employed, by $74,812 - 13,070 = 61,742$ calories.

3. *With Steam.*—To the amount of heat produced by the oxidation of 10 kilos. of silicon, say, 74,810 calories, must in this case be added the heat introduced with the oxygen at a temperature of 100 deg., which amounts to $11.429 \times 0.218 \times 100 = 24.9$ calories. The total generation of heat, therefore, amounts in this case to $74,810 + 249 = 75,061$ calories. For this the necessary quantity of oxygen, is, however, first to be obtained by the decomposition of 12.858 kilos. of steam, which contain 1.429 kilos. of hydrogen, and to effect this decomposition $1.429 \text{ kilos.} \times 29,638 = 42,353$ calories are consumed, besides which the hydrogen escaping from the bath carries away $1.429 \times 3.40 \times 1,300 = 6,316$ calories. There are consequently consumed in all $42,353 + 6,316 = 8,669$ calories, so that for heating the bath there remains in this case per ton of pig iron employed $75,061 - 48,669 = 26,392$ calories for every per cent. of silicon oxidized with steam.

Even assuming the higher value of the specific heat of hydrogen, there arises consequently, in this case, an increase of temperature; but it is very remarkable, however, that this only takes place during the

* The calorimetric effect of silicon is, according to Troost and Hautefeuille ("Dingler's Journal," vol 194, page 55), 7,830 calories.

combustion of silicon, for the oxidation of iron, and especially of carbon, by means of steam produces, on the contrary, a cooling effect. By this, moreover, is also explained the circumstance that the advantages which at times seem to accrue from the use of steam are chiefly experienced at the commencement of the converting process of puddling.

To obtain a more comprehensive view, we will now group together, in one table, the conditions of heat which arise during the combustion, with atmospheric air, of a unit in weight of the principal substances present in pig iron, viz., iron, carbon, and silicon.

With reference to this Table it should, however, once more be observed, in the first place, that the specific heat of the gases have been calculated as if the gases had always had the opportunity of free expansion, or, in other words, as if their pressure had been equal to that of the exterior air, and in the second place, that no account has been taken of the heat conducted away and radiated by the walls of the furnace; also that the products of combustion have been assumed to pass off from the bath at the same temperature as the latter was considered to possess at the commencement of the process, viz., 1,490 deg. C.

The Oxidation of 10 kilos. of	Iron	Calories.	Carbon	Calories.	Silicon	
	kilos.		kilos.		kilos.	
Requires of atmospheric air	12 42	..	57 9[illegible]	..	49.69	..
Which contains: oxygen	2.85	..	13 33	..	11.43	..
nitrogen	9 57	..	44.66	..	38.26	..
In the combustion are generated	..	12013	..	24730	..	78300
From these deduct the heat which is						
(*a*) carried away with the carbonic oxide	..	..	4718	..	..	..
(*b*) absorbed by the slag	1520	..	..	..	3480	..
(*c*) carried away with the nitrogen	3209	..	15260	..	13070	..
Or in all	..	4789	..	19978	..	16558
For heating the bath there consequently remain, per cwt. of pig iron employed, for every per cent. of the respective substances which has been oxidized	..	7224	..	4752	..	61742

Messrs. Jordan and Kupelweiser assume, as before intimated, the caloric effect of manganese to be the same as that of iron, and do not, therefore, ascribe to the manganese contained in Bessemer pig iron any beneficial influence on the heating process. In as far as the temperature depends on the composition of the pig iron, they consider, in accordance with the calculations here imparted, that it is virtually determined by the proportion of silicon present in the pig iron bath, to produce a sufficient degree of heat, should amount, it is estimated, at the very least, to 1.25 per cent.

The figures presented in our last article appear in fact to make it clear that the charge must become more heated the more silicon is contained in the pig iron, provided only that the blast is strong enough to allow the process to be completed with sufficient rapidity, notwithstanding the presence of a larger proportion of silicon* and also that the bath is deep enough for the complete utilization of the oxygen in the blast, even if by reason of the increased proportion of its silicon, the pig iron should have become less disposed to absorb oxygen, of which tendency we shall have more to say further on. But even admitting this powerful action of silicon in generating heat, it in nowise follows as a necessary consequence that the presence of manganese may not exercise a much greater influence on the generation of heat in the Bessemer process than Messrs. Jordan and Kupelweiser have assumed. That such is indeed the case, seems to be demonstrated by the experience acquired at one or two Swedish Bessemer works, and, as a proof of this, it may suffice to state, that at one of the said works, where the pig iron usually contains nearly 3 per cent. of manganese, but only the inconsiderable proportion of 0.7 per cent. of silicon, the charge generally seems to have a higher temperature than at most Bessemer establishments. It is by no means to be inferred from this, however, that the charges at the works in question might not be still hotter if the force of the blast-apparatus would allow of a greater proportion of silicon in the pig iron; but, under all circumstances, it seems to follow as an undoubted consequence, that in this respect

* See "Illustrated Technical Journal," Stockholm, 1871, page 107.

the presence in the Bessemer pig iron of a proportion of manganese up to as much as 3 per cent. must be very desirable. Whether this, on the other hand, is particularly advantageous, as regards the final result, is a matter which cannot, probably, be so unconditionally affirmed; for a Bessemer pig iron holding much manganese, will sometimes produce a steel very much impregnated with that substance, and there are, at any rate, not wanting reasons for supposing that steel, as well as iron, holding a considerable proportion of manganese, will be more sensible to concussion than those metals more free from manganese, and that the presence of manganese increases the tendency to crack, and causes the iron to act with a greater corrosion on the moulds. Be this as it may, however, it is a fact that most of the Swedish blast furnace charges are not in any appreciable degree impregnated with manganese; and at such places where the Bessemer process is to be adapted to charges so impregnated, it is all the more necessary, in order to obtain a hot charge, that the blast apparatus should have sufficient force* to enable the operator to employ a pig iron rich in silicon.

As long as the calorimetric heating effect of manganese remains unknown, it is plain that it cannot be stated, in exact figures, how much heat its combustion furnishes to the Bessemer process; but on the other hand, the amount of heat available for the bath when a pig iron free of manganese is treated according to the said process, can always be easily computed, with the assistance of the calculations shown in the foregoing, provided only that it can be demonstrated what quantity of each particular substance is oxidized in the process.

Messrs. Jordan and Kupelweiser estimated these quantities in a normal Bessemer process at 2 per cent. of silicon, 4.25 per cent. of carbon, and 8.75 per cent. of iron; but, as corresponding more closely with the condition of our Swedish manufacture, I will assume them to be

1.00	per cent.	silicon
4.25	"	carbon
6.00	"	iron

There would in this case be available per cent. of pig iron employed, to increase the temperature of the bath during this process:

1.00 × 6174.2	= 6174.2	calories
4.25 × 475.2	= 2019.6	"
6.00 × 722.4	= 4334.4	"
Total, ...	12,528.2	

The specific heat of molten iron is as yet not known, but as in the case of molten pig iron, it is about 50 per cent. higher than that of pig iron from 0 deg. to 200 deg., and as the specific heat of iron at the usual degree of temperature is 0.11, the specific heat of molten iron may be set down at about 0.16. The temperature of the bath would in consequence be increased, during the process, to the extent of 12,528 : 16=783 deg., and, as its original temperature was 1,400 deg., the final temperature would, in that case, be about 2,200 deg. As no method has hitherto been invented by which such high degrees of temperature as those just mentioned can be measured, it is obviously impossible to know for certain how nearly this estimated degree of heat coincides with the real fact; but that the figure derived from the said calculations cannot be far from the truth seems to be established by Kupelweiser's observations on the fusibility of platina in molten Bessemer metal. During his experiments at Heft, he found that a tolerably thick piece of platina wire, inserted in the jet of soft iron running out from the Bessemer furnace, was fused in a few seconds, but when a little specular iron had been added to the ladle, and the steel had been run into the moulds, a platina wire inserted in the still perfectly liquid metal was not fused at all. As the degree of heat requisite to fuse platina is, according to the investigations of Sainte Claire Deville, below 1,900 deg., it would appear that the temperature of 2,200 deg. assigned to the Bessemer iron, on completion of process, has much probability.

In the foregoing has been shown what influence is exercised by the composition of the pig iron on the amount of heat generated in the Bessemer process, but the temperature attained is not, however, exclusively dependent on this and on the specific heat of the bath, but also on the time required for the combustion, inasmuch as the loss of heat by external cooling, must be greater in proportion as the process is protracted. It is, therefore, not enough that certain percentages of the substances

* See "Illustrated Technical Jeurnal," Stockholm, 1871, page 115.

entering into the composition of pig iron undergo combustion during the process, for unless a considerable portion of the heat generated thereby is to be wasted, the combustion must, besides, be effected with great rapidity; but for this purpose an abundant supply of blast is necessary, a supply which cannot be procured except by a powerful blast apparatus.*

The degree of heat imparted to the walls of the furnace before the introduction of the pig iron will also considerably influence the cooling which takes place through radiation from the said walls, besides which it is evident that the amount of heat lost per weight unit of pig iron through the walls, must be less in proportion as the quantity of pig iron under treatment is increased; for, if the furnaces are properly constructed, the surfaces of their walls will not be augmented in a ratio proportionate to the space within, from which it follows that the loss of heat will be comparatively less in working with greater charges.

In the calculation of heat hereinbefore specified, no account has been taken of the cooling through the walls just mentioned, and as this cooling cannot be entirely prevented, even with the best heated furnaces and the heaviest charges, and the greatest acceleration of the process, it is evident that the conclusions as to temperature mentioned above must be a little too high, unless the cooling in question may be compensated by the circumstance that, on the other hand, no account has been taken of the rise in temperature which must be caused by the gases leaving the furnace under a pressure depending on the size of the nozzle, but more or less exceeding that of the atmospheric air.

When gases expand it is known that they absorb heat, which is again liberated on their being condensed in a corresponding degree. It is evident, therefore, that the higher the pressure sustained by gases on their escape from a furnace, the less heat do they carry away with them, and the higher, consequently, will the degree of temperature in the furnace be, other conditions being assumed to be equal. From this it follows that the narrower the aperture is for escape of products of combustion from a Bessemer furnace, the hotter the charge must be, provided always that the blowing apparatus has force enough to be capable of pressing in the same quantity of air, notwithstanding the increased resistance, so that the process is not retarded by reason of the contracted aperture of the nozzle.

As already stated, no account has been taken in the foregoing calculations as to heat, of the rise in temperature occasioned by the circumstance just adverted to, but owing to the difficulty of determining which of the figures comprised between the two extreme limits denoting the quantities of specific heat (for constant pressure and constant volume) may be the correct ones, they have, in accordance with M. Jordan, simply been estimated at the same degrees as if the gases, in escaping from the Bessemer furnace, had only the pressure of the surrounding atmosphere. What component part of the pig iron, the calorific action of which during combustion with atmospheric air has the least justice done to it by this estimate, is the carbon, inasmuch as the combustion of this substance produces the greatest quantity of gas; but in order to indicate the limits within which the error thus committed must lie, it has been explained in a foot note how the result would turn out if it could be allowed to compute the specific quantities of heat in the gases as low as in their state of constant volume.

The calculations of heat presented in the foregoing are based on the assumption that during the rising of the atmospheric air through the Bessemer bath, the whole of its oxygen is completely utilized, so that only the nitrogen contained in the blast, but no part of its oxygen escapes from the bath in a free form. If, on the other hand, the oxygen should not be completely absorbed by the metal, a loss of heat will be the natural consequence; in the first place because the generation of heat in a certain moment of time is diminished in the same proportion as the utilization of oxygen is lessened, or the refining process retarded, and in the second place because the free oxygen, just like the nitrogen, absorbs heat, which escapes, without profit, with the oxygen from the furnace.

The waste of produce, moreover, will also be somewhat increased by this, because the gases which fill the furnace are, in this case, oxidized, and therefore, in

* Respecting the basis of calculation of the force required for the blast of the Bessemer furnace, I take the liberty of referring to my article in the "Illustrated Technical Journal," of Stockholm, cited in the foregoing.

their turn, oxidize a portion of the iron bubbling at the surface, partly converting it into oxide of iron, which is not retained in the slag, but escapes as a reddish-brown smoke with the gases.

If the air is forced too quickly through the bath the latter will not have time to absorb the whole of the oxygen, and the more or less complete utilization of that substance by the same description of pig iron depends, in consequence, on the time occupied by a particle of air in ascending through the bath.

Again, the time of contact between the metal and the blast is increased with the depth of the bath, but decreases with the pressure of the blast, and it is clear, therefore, that already, on this account, the depth of the bath and the pressure of the blast must be made in some measure to correspond. Furthermore, it is hereby made equally clear that in a cupola converter with vertical tuyeres placed at the bottom, so shallow a bath cannot be profitably employed as will be practicable in a Bessemer converter with horizontal tuyeres, for in the first-mentioned description of converter, the blast goes the nearest way straight up through the bath, while, in fixed converters, on the contrary, it must describe a curved line chiefly depending as to extent on the pressure of the blast and the depth of the bath. Even in a cupola converter, however, the depth of bath need probably not require to be increased in full proportion to the blast pressure, for the stronger this pressure is, or the harder the blow of the blast, the more intimate should the contact become between the air and the particles of iron, and the more easily would, therefore, the metal be enabled to absorb or utilize the oxygen.

The absorption of oxygen does not appear, however, to depend exclusively on the circumstances hitherto dwelt upon, but just as different descriptions of pig iron at their tapping from the blast furnace already show different dispositions for being oxidized, some of them sparkling or burning a great deal more than others,* so it has, in like manner, appeared at the Swedish Bessemer works, as if Bessemer pig irons of different compositions were more or less ready to absorb oxygen; a grey pig iron seeming to require a longer period of contact between the particles of air and iron and a stronger blast pressure, for a complete absorption of the oxygen of the blast, than a less grey or white iron. It is therefore necessary, in order completely to utilize the oxygen of the blast to increase the depth of the bath in proportion to the quality of the pig iron.

In the contrary case, or if while employing a more than usually grey pig iron, the depth of the bath should be made as shallow as could possibly be compatible with the absorption of the oxygen by a whiter, or No. 3 pig iron, it would, in most cases, happen during the first so-called refining or slag-forming period, that the before-mentioned reddish-brown smoke which is produced by an incomplete utilization of the oxygen, would make its appearance, accompanied, moreover, and from causes explained above, by a decrease of heat in the process.

Although, under usual circumstances, the silicon is mostly oxidized before the carbon, or during the slag-formation period, while the combustion of the carbon principally takes place during the boil and the after-refining, it is nevertheless probable that the chief cause of a lessened disposition in pig iron to absorb oxygen, will be found in the larger proportion of silicon which it contains.

It has already been shown in the foregoing, that the richer in silicon the Bessemer pig iron is, the hotter will the charge become, provided that the greater admixture of silicon does not retard the process too much, nor prevent a complete utilization of the oxygen of the blast. But in order that these conditions may be fulfilled, it is again evident from the reasons above given, that the more grey and the more rich in silicon is the pig iron to be operated upon, the more abundant must the supply of blast be, and in consequence, the greater is the force required; the more so as a very dark and graphitic pig iron usually is comparatively thick-flowing, and, consequently, offers greater resistance to the blast.

One foot is considered about the ordinary depth of bath for the Bessemer vessel; less than that would hardly suffice to insure proper success when making use of a moderately hard pig iron free from manganese, and a pretty considerable blast pressure.

* The difference in degree of temperature of the pig iron exercises, no doubt, in this respect a very material influence, causing the warmer of two otherwise similar descriptions of pig iron to burn fiercer than the cooler of the two; but it is a known fact, that even if the temperature is the same, two different classes of pig iron may exhibit a very dissimilar disposition to burn or throw sparks while running out from the blast furnace.

Having thus, in general outline, touched on the usual circumstances which produce more or less heat in the charge of a Bessemer furnace, we will now, in conclusion, endeavor to ascertain also what influence, in this respect, may be expected from sundry projects, either already essayed in some place or another, or altogether untried, to obtain sufficient heat in the Bessemer process, even with a No. 3, or white pig iron.

As, generally speaking, no separate fuel is employed in the Bessemer process, it readily suggests itself to try the use of such fuel for raising the temperature in this process as in others. With this view experiments were commenced at Neuberg as early as the year 1867, to inject charcoal dust with the blast; a procedure which is said to have been afterwards generally continued at that place, and likewise to have been tried, at least at intervals, at some other Bessemer works. That the degree of heat will be somewhat increased hereby is natural, but it is equally obvious, that if the process is to be finished off with the same rapidity when charcoal dust is being injected as when it is not, the supply of blast must be more abundant than otherwise, inasmuch as part of the air is consumed for combustion of the injected charcoal. The main question is, however, whether the charcoal employed in this manner is utilized to greater or less advantage than if it were used in the blast furnace to produce a more grey or No. 1 pig iron.

As has been already shown, the combustion of 10 kilos. of the carbon of the Bessemer bath, with atmospheric air, produces an increase in heat of 4,752 calories, but the injected charcoal dust does not possess the same temperature as the carbon contained in the pig iron; it must first be heated up to that point in the bath, for which purpose $2.4 \times 1,400 = 3,360$ calories are consumed, and the accession of heat obtained by combustion of 10 kilos. of injected charcoal dust is consequently reduced to $4,752 - 3,360 = 1,392$ calories, which would scarcely suffice to raise the temperature of 1 ton of molten iron 9 deg. Were the object, therefore, by the injection of charcoal dust, to make up for the heat generated by a portion, say, 0.5 per cent. of silicon contained in the pig iron, it would be necessary, inasmuch as the combustion of 0.5 per cent. of silicon increases the heat of the Bessemer bath by $61,742 \times 0.5 = 30,871$ calories, to inject $30,871 : 1,392 = 222$ lbs. of pure carbon, or nearly 5 bbls. of charcoal for every ton of pig iron.

As, moreover, Professor Kupelweiser has made the observation that a portion of the charcoal dust has not, in point of fact, the time requisite to be consumed in the metallic bath, but that its combustion is first effected outside of the neck of the retort, it seems to be clear that the action of so inconsiderable a charcoal injection as it is customary to make at Neuberg, or three to five per cent. of the weight of the pig iron, cannot produce any very appreciable effect; in full confirmation of which Herr Kupelweiser has also stated that it can scarcely be discerned by impartial investigators. It further follows from this, that it can scarcely be in accordance with good economy, as long as cold blast is used, to substitute an injection of charcoal dust into the Bessemer furnace, for the consumption of charcoal which would be requisite to produce in the blast furnace a pig iron sufficiently grey to obtain by it a high degree of heat in the Bessemer process, especially as such can be produced without any additional consumption of charcoal, if only the stove is powerful enough to supply the blast furnace with a highly heated blast.

A plan, advocated by Messrs. Styffe and Tunner, to raise the temperature in the Bessemer process, is to employ heated blast, and a prize of 1,000 florins has been offered in Austria for a successful realization of this idea.

Having regard to the great amount of blast-power required for the Bessemer process, and to the considerable quantity of gases which in a highly-heated state escapes from the furnace, it is not difficult to conceive that the heating of the blast ought to insure material advantages, but for this purpose it is necessary that the blowing apparatus shall be sufficiently powerful to be able, notwithstanding the attenuation of the air caused by its higher temperature, to force in so large a volume of it that the process may be completed with the requisite rapidity.

If the additions of heat, which are supplied to the Bessemer bath by combustion with atmospheric air at different degrees of temperature of 10 kilos. of iron, carbon, and silicon, are calculated in the same manner as has previously been done with unheated blast, and if the specific heat of

oxygen is assumed to be 0.2182, the following quantities of heat will result:

		Of 10 kilos. of iron.	Of 10 kilos. of carbon.	Of 10 kilos. of silicon.
	Deg. temp.	calories.	calories.	calories.
With blast of	0	7224	4752	61742
"	100	7520	6133	62925
"	200	7816	7514	64100
"	300	8112	8895	65291
"	400	8408	10276	66474
"	500	8704	11657	67657
"	600	9000	13038	68840

The greater the quantity of oxygen required for the combustion of any given substance, the greater will naturally be the accession of heat obtained from the heating of the air by that substance. Consequently the accession of heat obtained, by heating the blast, is comparatively greater from the carbon than from either of the other substances.

Let us now see what accessions of heat would be produced with blasts of different temperatures per ton of Bessemer pig iron of such a description that in conversion there would be oxidized at a blast temperature—

	Of 0° calories.	Of 100° calories.	Of 200° calories.	Of 300° calories.	Of 400° calories.	Of 500° calories.	Of 600° calories.
1.00 per cent. of silicon.....	61742	62925	64108	65291	66474	67657	68840
4.25 " carbon.....	20196	26065	31934	37804	43673	49542	55411
6.00 " iron..... ...	43344	45120	46896	48672	50448	52224	54000
	125282	134110	142938	151767	160595	169423	178251

These accessions of heat would—if the specific heat of the molten iron is assumed to be 0.16, and no account is taken of the slag which had been formed—for the several degrees of temperature of the blast correspond to the following increments in the temperature of the bath:

Degrees.						
783	838	894	948	1004	1059	1114

It is clear, therefore, that if the bath of Bessemer pig iron, in order to attain a sufficiently high degree of temperature, only requires the accession of a certain amount of heat, it is possible to employ in the Bessemer process, without detriment, a pig iron less grey in proportion as the temperature of the Bessemer blast is raised. In this manner it is easy to calculate that, with a blast heated to 500 deg., there should not be required a greater proportion than 0.35 per cent. of silicon in the pig iron, to obtain as great a heat during the process as can be produced with a pig iron containing one per cent. of silicon when the blast is not heated. But, as has been stated above, it is necessary for this purpose that the blast apparatus should be so powerful that the conversion with heated blast can proceed as rapidly as with cold; and, if to this is added, first, the circumstance that the loss of heat in a Bessemer heating apparatus must be very considerable in places where the intervals between the blowings are so long, as is usually the case with us in Sweden, and then and principally the increased difficulty which undoubtedly arises from the heating of the blast, to keep the tuyeres in proper order, it may perhaps still be a question whether it will not be cheaper, when the injection of charcoal dust is not simultaneously resorted to, to procure, with the assistance of powerful heating apparatus for the blast furnace, and without extra consumption of charcoal,* a sufficiently grey, or No. 1 pig iron, to be able to dispense with the Bessemer blast heating apparatus altogether.

If, on the other hand, the Bessemer hot blast can, in some way, and without the too rapid destruction of the tuyeres, be combined with the injection of charcoal dust, its action ought, as was first pointed out by Kupelweiser, to be very powerful, and it would even appear as if in that case a pig iron, almost as poor in silicon as that used for refining in the charcoal hearth process, might be employed with advantage in the Bessemer process. For 10 kilos. of charcoal burnt in air heated to 500 deg., would increase the heat of the Bessemer bath by 11,657 calories, while 3,360 calories would be required to heat the charcoal from 0 deg.

* See the "Annals of the Iron Office," Stockholm, 1871, p. 268.

to the initial temperature of the bath, and the accession of heat produced by 10 kilos. of charcoal would therefore, in this case, amount to 11,657 − 3,360 = 8,297 calories. The quantity of heat infused into the Bessemer bath by the combustion of 0.5 per cent. of silicon with cold air, might, therefore, when the blast is heated to 500 deg., be indemnified by the injection 0.5 × 61,742 : 8,297 = 37 kilos. carbon, or about 0.7 of a barrel of charcoal per ton of pig iron.

To arrive at a correct estimate of the effect produced by the Bessemer hot blast in combination with the injection of charcoal dust, it should be observed, in conclusion, that in the calculation last made no account has been taken of the influence which the heating of the blast to 500 deg. in itself exercises on the temperature of the bath; but about this something had been said previously.

Another method of raising the temperature in the Bessemer process would be to inject oxygen gas, but in regard to this the question arises, whether such gas can be procured at so low a cost that its use would bring any advantage, and in order to estimate this, we will, in the first instance, examine how great the accession of heat to the bath would be if the conversion were effected with pure oxygen:

		calories.
10 kilos silicon 42.5 " carbon 60.0 " iron	in combustion with unmixed oxygen increases the heat of the bath with	10.0 × 74812 = 74812 4.25 × 20012 = 85 5 6.00 × 10493 = 629.8
		222821

The amount of heat generated by the oxidation of the above assumed quantities of silicon, carbon, and iron, would therefore be sufficient to raise the temperature of the bath nearly 1,400 deg., and even if all the heat proceeding from the silicon were deducted the bath ought consequently, when converted with oxygen, to be 100 deg. hotter than has been considered necessary for an average temperature of the process. The use of unmixed oxygen, however, could hardly come into question, but if employed, it would probably be in an admixture with atmospheric air, and if in order to ascertain the value of oxygen in this respect, it is desirable to investigate, for instance, how much extra oxygen would have to be mixed with the air to produce the same increase of temperature in the refining of the pig iron above treated of as would result, without an extra admixture of oxygen, by heating the atmospheric air to 500 deg., it will be found that for this purpose the air must be mixed with barely 19 per cent. of its weight, or 17.3 per cent. of its volume of oxygen. The nitrogen present in unmixed atmospheric air takes away from the bath, for every ton of pig iron, 222,821 − 125,282 = 97,539 calories, which loss of heat, if the temperature of the bath is to be the same as when a blast heated 500 deg. is employed, must be brought down to 222,821 − 169,423 = 53,398 calories. But in order to make this possible the quantity of nitrogen per ton of pig iron must not exceed 53,398 : (0.244 × 1,400) = 156.32 kilos., which is contained, together with 46.68 kilos. of oxygen, in 202.9 kilos. or 2,536 cubic feet of atmospheric air, while for the said purpose are required 370.6 kilos. or 4,630 cubic feet of unmixed air at 0. deg. temperature and a medium barometric pressure, to which the quantities of air and oxygen are here always reduced. To oxidize the stated proportions, per ton of pig iron, of the several constituents of the pig iron, requires in all 85.24 kilos. of oxygen, of which consequently in the case before us 85.24 − 46.68 = 38.56 kilos., or 440 cubic feet, per ton of pig iron, must be intermixed with the atmospheric air.

That an entire or partial exchange of the Bessemer blast for steam would not be attended by a higher, but on the contrary by a considerably lower temperature than when air alone is employed, can be easily gathered from the calculations presented at the beginning of this memoire, inasmuch as they show that in Bessemer refining with steam it is only the silicon that, in being oxidized, affords any accession of heat, while the oxidation, as well of the iron, as especially of the carbon, on the other hand, are attended with a positive lowering of the temperature. As the silicon is chiefly oxidized during the commencement of the process, it is only at that stage, or during the refining period, that there should ever be any question of injecting steam, and the object of so doing would in that case be to eliminate sulphur in some degree; but even at this stage the introduction of steam will produce a less elevation of temperature than would have been attained by the injection of a corresponding quantity of air.

It has also been proposed to inject, through concentric double tuyeres, air and hydrogen,

to form water by combustion, and thus produce an increase of temperature. But the water which is formed in this way would, in ascending through the bath, be again decomposed, and thereby absorb just as much heat as was engendered by its formation. The consequence of such an arrangement could, therefore, hardly be any other than a cooling proportionate to the injection of hydrogen, for no heat can very well be generated by the hydrogen in such a manner. In fact, the latter will in this case rather compare with nitrogen, and will, like that gas, while rising through the bath, absorb heat and then carry it away from the furnace, while on the other hand the only heat engendered would have been produced by the injection of air alone.

ON THE CONVERSION OF LIME INTO CEMENT BY THE SELENITIC METHOD, AND THE ECONOMY AND OTHER ADVANTAGES OF THE PROCESS.*

Professor Abel, in his official report on the scientific inventions exhibited in the International Exhibition of 1871, remarks: "There are few scientific inventions now exhibited which give promise of becoming of greater practical importance than that of the so-called 'Selenitic Mortar,' for which we are indebted to Major-Gen. H. Y. D. Scott, C. B., and which is the latest and decidedly the most useful of the numerous results obtained by that officer in the course of the valuable researches, both scientific and practical, which he has carried on for many years past on the nature, productions, and applications of cements and hydraulic limes."

It was observed by Sir C. Pasley, in his valuable treatise on limes and cements, that he had "no doubt but that the blue lias lime would unite stones together nearly as powerfully as the best cements are capable of doing, if it did not swell in all directions when the attempt is made to combine the two processes of slaking and setting, which take place simultaneously in cements, without increase of bulk, and consequently without forcing them to split or detach themselves from stones or bricks." The invention of the selenitic method enables the processes of slaking and setting to be combined without the ill consequences to which General Pasley alludes. By a very simple and economical expedient the tendency of hydraulic limes to swell and split on being mixed with water is completely brought under control, and in many of their applications their mortars are made to exhibit greater cohesive and adhesive force than is met with in the strongest cements.

"General Scott," says Professor Abel, in the report already quoted, "was the first to observe, about sixteen years ago, that a limestone which does not possess to any useful extent, if at all, the characters essential to its conversion by burning into a hydraulic lime, may be made to furnish a good cement by simply allowing a small proportion of sulphurous acid gas (obtained by burning sulphur, or other well-known methods) to pass into the kiln during the burning of the lime. The latter when subjected to this slight modification of the ordinary kiln treatment, instead of slaking, or combining rapidly with water, with considerable evolution of heat, undergoes only gradual hydration, unattended by any important elevation of temperature, and sets or hardens after a time, behaving, in fact, in every way like a cement of good quality, and sometimes equalling Portland cement in strength. The production of the so-called Scott's cement by this simple modification of the lime-burning process, has been carried to some extent for a number of years, and a medal was awarded to Colonel Scott in 1862 for its invention; but some practical difficulties attended the production of uniform results, and these appear to have retarded any very considerable adoption of this method of manufacturing cement." It was found that in lime so treated a small proportion of calcium sulphate, seldom exceeding 5 per cent., and frequently below that proportion, was formed; and that an admixture of a corresponding quantity of a soluble sulphate, or of sulphuric acid, with the lime, yielded similar results; "but the difficulty of securing uniformity in the influence exerted by the sulphate upon the lime when employed in this manner upon a scale of ac-

* From a paper read before the British Association by Gen. H. Y. D. Scott.

tual practice, precluded the attainment of successful practical results. "By a most simple modification," Professor Abel continues, "in the mode of applying them, General Scott has now brought the peculiar influence which sulphuric acid, or a sulphate, exerts in preventing the heating and promoting the setting and hardening of lime, to bear with perfect success and uniformity upon lime of the ordinary kind used for mortar and plastering purposes. The sulphuric acid or sulphate (which may be called the selenitizing agent) is first mixed with the water to be used in making the plaster or mortar, in the proportion corresponding to about 5 per cent. of calcium sulphate upon the lime used." The lime is then added, and these ingredients are triturated together until they form a creamy paste, after which the paste is mixed with the requisite proportion of sand for the production of the quality of mortar required.

The invention is applicable to a variety of uses, but chiefly to the production of mortar for ordinary building purposes, to plaster work, and to making concrete. It is also adapted to brick making, and the preparation of building blocks of any size and in any ornamental form. The Messrs. Bodmer have succeeded in producing with it bricks that are almost as hard as marble, and have faces of great beauty of texture and color. According to the proportion of sand employed in the mixture, either a very smooth surface, or one resembling that of a granulous freestone, but very much harder, can be obtained. The Scott's cement and the selenitic mortar have been tested in a variety of ways, and by different persons, as to their powers of resisting crushing forces and tensile strains, and in all cases the results have been highly satisfactory. Amongst those who have experimented with it are Major Schaw, Professor of Fortification at the Staff College; the late Capt. Fowke, R. E.; Col. Gallwey, Commandant of the Military School of Engineering at Chatham; Col. Graham, V. C.; Mr. A. W. Colling, Clerk of Works at the New Law Courts, for Mr. Street, R. A.; ank the Messrs. Lucas Brothers. The material has also been made the subject of careful experiment by Mr. David Kirkaldy, at his testing works in Southwark.

Major Schaw assigned to plasters of the following lines and cements, after three years' exposure, the relative resistances given in Table I. The trials were made by breaking the plaster with blows of a hammer and by scratching with a sharp tool.

TABLE I.

Name of lime or cement.	Nature of mortar. For 1 measure of lime or cement.		
	1 Sand.	2 Sand.	3 Sand.
Lias lime used in the ordinary manner	4.5	4.0	3.5
Roman cement	6.5	4 5	2 5
Medina "	9 0	7 0	4 5
Scott's cement, prepared from Halling lime	10 0	7.5	7.0
" prepared from lias lime*	10 0	7.7	6 2
White's Portland cement	10.0	8 5	8.0

* Three months old only.

In experiments made at Newhaven in comparison with lias lime, Colonel Graham found the relative strength of the Scott's cement and this lime, with the same proportion of sand, to be as three to one when subject to a tearing force, and as five to one to a crushing force. Colonel Gallwey's experiments at Portsmouth, where the material has been largely used in the new fortifications, were equally conclusive as to the advantages in economy and strength which were gained by the use of Scott's cement. A series of experiments were made at the New Law Courts by the clerk of the works, Mr. A. W. Colling (Mr. Street, R. A., architect), on Halling grey lime and the lias lime from Barrow-on-Soar, to test this system, and the results

given in the following table were obtained. The resistances were arrived at by pulling asunder two bricks united crossways so as to give a joint having an area of $18\frac{1}{4}$ in. One month was allowed for setting. In every case the mortar was made in a mill, and three samples of each material were tested.

TABLE II.

Material and mode of preparation.	Measures of sand to one measure of lime	Mean resistances in lbs.
Lias grey lime, as common mortar	3	112
" " selenitic "	6	209¾
Barrow lime, as common "	3	125
" " selenitic "	5	283¾
" " " "	6	196

In this series of experiments, therefore, the selenitic method of preparation, with a double proportion of sand, gave nearly double the resistances attained in the ordinary mode of using lime. The experiments of Mr. David Kirkaldy are, if possible, still more conclusive, for, having been conducted by that gentleman with the accuracy and care for which he has rendered himself eminent, they are beyond dispute.

The trials were made on blocks of mortar having a base area of 7.84 sq. in., with bricks bedded together crossways and pulled apart; and with blocks having a sectional area of 5 sq. in., somewhat similar in form to those employed by Mr. Grant in testing the strength of Portland cement. The first was used to ascertain the resistance to crushing; the two last that to tensile strain. The lime used was from the Burham pit of Messrs. Lee, of Holling.

TABLE III.

Nature of Material.	Parts of sand to 1 of lime, average.	Resistances in lbs. per square inch.		
		Thrusting stress.	Pulling stress.	
			Bedded Bricks.	Blocks.
Common mortar "gauged"	3	121 7	7.67	23 6
Selenitic mortar "gauged"	5	284.5	16 65	63.6
Selenitic mortar "pressed" with trowel and "gauged" with a minimum of water	5	629.6	—	83 0

The superior adhesion of selenitic mortar to smooth surfaces was markedly shown in experiments made in comparison with Portland cement by bedding two flooring tiles crossways. After 14 days being allowed for setting, the average resistance of the Portland cement mixed with two parts sand to one of cement was 56 lbs., the cement in most cases completely leaving one of the tiles. On the other hand the selenitic mortar gauged with five parts of sand to one of lime, when similarly tested, always broke through the joint, and resisted fracturing until weighted with 158 lbs. This is not the only application in which selenitic mortar shows a superiority to Portland cement.

Selenitic mortar in ordinary dry brickwork, with four or five parts of sand and upwards, will give greater strength than Portland cement used under similar conditions. This will appear from the following table, which indicates the resistances in pounds to a longitudinal or transverse strain. The experiments were made by Mr. Gilbert Redgrave, A. I. C. E. The lias lime employed for the selenitic mortar was that from Barrow-on-Soar, and the grey lime was from the Burham pit of Messrs. Lee.

The whole of the samples were prepared by Mr. Hartley, late Royal Engineers, who has had many years' practice in experimenting on the resistances of mortars.

TABLE IV.

Nature of material.	Age in days when fractured.	Parts of sand to 1 of cement or lime.				Nature of trial.
		3 Sand.	4 Sand.	5 Sand.	6 Sand.	
Portland cement	28	—	463	325	313	Bricks bedded cross-ways, area of joint being 20 in.
Barrow selenitic	28	541	418	399	399	
Burham "	28	484	454	368	408	
Portland cement	35	—	520	433	309	
Barrow selenitic	35	435	539	438	430	
Burham "	35	444	430	490	556	
Portland cement	209	668	476	344	190.5	Prisms 2 in. square in section, loaded at centre, distance between points of support 3 in.
" "	131	—	680	464	470	
Barrow selenitic	203	—	740	776	6 8	
Burham "	230	—	806	722	876*	
Portland cement	167	—	206	149	113.5	Briquettes 2¼ in. square in section at neck, subject to longitudinal strain.
Burham selenitic	161	255	—	—	250	
" "	165	—	—	170	210	
" "	234	—	340	—	—	

* Not broken.

In the same series of experiments that the above table is compiled from, a comparison was made between the resistances of limes treated in the ordinary manner and the same limes seleniticized, with results very similar to those obtained at the New Law Courts and by Kirkaldy. Mortar joints of 20 sq. in. area, between bricks bedded transversely, were fractured, after 28 days, with the following weights acting by tension.

TABLE V.

Nature of lime.	Parts of sand to 1 of lime.	Resistance in lbs.
Barrow lime in ordinary mortar	3	183
Barrow lime seleniticized	3	399
White chalk lime, ordinary mortar	3	93
White chalk seleniticized	6	2 8
Burham gray lime, ordinary	—	not tested.
Burham gray lime, seleniticized	6	408

The results given in the foregoing tables, obtained as they were by different experimenters, at different times and with different supplies of lime for each set of trials, demonstrate conclusively the great accession of strength which is conferred on lime mortars by the selenitic mode of preparation, whether exposed to a thrusting or a pulling force, and the results of practice confirm those of experiment. In the case of an arch in a wall at the South Kensington Museum, built by Captain Fowke in Scott's cement with four parts sand, which had to be destroyed, the great resistance of the mortar was made apparent. The wall was 1 ft. 6 in. thick, and in making alterations one-half of the arch had been cut away, and at the other half the brickwork had been cut through at the skewback, so as to leave a depth of 3 ft. 3 in. to support the weight of the half arch and of the load put upon it. The beam thus formed was then loaded at the extremity at a distance of 6 ft. 8 in. from the point of support, and it required as much as 1 ton 8 cwt. acting with this leverage to fracture it.

An important feature in connection with the selenitic method is the fact that the best limes for the purpose are those which, forming the boundary between limes and cements, are with difficulty used as either. This difficulty arises from the inequality in the relative proportions of lime and clay in the different layers of the material. Portions of them, if used as lime, will not fall to powder on the attempt being made to slake them, unless the process is conducted with exceeding care, and such refractory portions are liable to slake and swell after they have been introduced into the work. If, again, the attempt be made to use them as cements by grinding them to powder. and then making them into mortar in the ordinary way, the expansion in setting is too great to enable the mortar to be used with safety. Nevertheless, these limes have the hydraulic or water-setting properties in the highest degree, and it is of considerable importance both to the engineer or architect and the manufacturer, that they should be utilized. As examples of such limes, those prepared from the so-called "soap" beds of the lower chalk, and the "good-for-nothing" beds of the lias at Barrow-on-Soar, may be instanced.

Ample proof has now been given that in the process described in this paper there is an action which is worth the investigation of engineers and chemists. The writer of the paper has come to the conclusion that the loss by the lime of its chemical avidity for water is due to what is termed contact action.

We have, in mortar made by this process, lime undergoing a chemical change in the presence of sulphuric acid; as a nascent hydrate it prefers taking the sulphuric acid into combination as well as water, and the union of the three takes place with the generation of less heat than in the combination of lime and water alone. There is a somewhat analogous case in the union of silex, lime, and water, which combine with far less avidity than when the silex is absent. In the selenitic mortar, in fact, each particle of lime sets as a particle of plaster of paris, and then yields up its sulphuric acid to another nascent particle of hydrate of lime, and thus the so-called selenitic action is transmitted through the whole mass of mortar.

It may be cited in proof of this view that—(1) The presence of water is necessary to carry forward the influence exerted, whatever that influence may be. In moist air, lime, however intimately mixed with sulphate of lime, will slake just like ordinary lime. (2) If an imperfect mixture be made in water, of lime and sulphate of lime, the selenitic influence can be clearly seen to radiate from the scattered particles of sulphate as so many centres.

The greatly increased resistance imparted to mortars by the selenitic treatment, as compared with that which they exhibit when the lime is first slaked, is probably in great measure, if not wholly, due to the great density of the selenitic compound. In the act of slaking, grey lime, for instance, doubles its volume, and its hydrated paste has double the bulk of a mixture of selenitic lime and water.

ON THE EVAPORATIVE EFFICIENCY OF STEAM BOILERS.

By WM. P. TROWBRIDGE, Professor of Dynamic Engineering in the Sheffield Scientific School.

From "American Journal of Science and Arts."

Transfer of Heat.— The quantity of water which a steam boiler apparatus will evaporate in a given time depends primarily upon the temperatures to which those parts of the plates of the boiler, known as heating surfaces, are exposed. In the furnace, the heating surface is exposed to the radiant heat of the incandescent fuel, and to the contact of the heated gases; and in the flues, to the contact of the gaseous products of combustion alone. The temperature of fuel, and the initial temperature of the gases, depend on the intensity of the combustion or the quantity of fuel burned on each square foot of grate surface in a unit of time, and also on the kind of combustion which takes place: *perfect combustion*, in this connection, designating that in which no combustible gases or uncombined oxygen escape to the chimney. This condition is presumed to give rise to the highest possible temperatures in the residue of fuel, and in the escaping products.

The quantity of fuel burned, the constitution of the escaping gases, and the resulting temperatures, depend on the following conditions:

1. The quantity of air which passes through the furnace in a unit of time.

2. The amount of surface of the fuel with which this air comes in contact.

The quantity of heat transferred to the water within the boiler will then depend on the amount of heating surface exposed to direct radiation, the amount of heating surface exposed to the contact of the gases, and the *laws* of absorption or *transfer of heat* under these conditions.

The quantity of air supplied to the furnace, in a unit of time, depends upon the chimney, or other apparatus for producing the draft, and the surface of contact of air and fuel; upon the kind of fuel, size of lumps, thickness of bed, etc. There are other conditions which influence the evaporative efficiency of boilers, when the total heat of combustion is to be compared with the quantity of heat transferred to the water; such as the losses from imperfect combustion, diffusion of heat, escape of heat through the chimney, etc., making an aggregate of losses which must be estimated.

The following general discussion of the problems involved is given, as suggesting a mode of investigation which may lead to more satisfactory experiments on the laws of transfer of heat.

Let Q represent the quantity of heat transferred to the water of the boiler in a unit of time, one hour for instance.

Q_1 the portion of this heat which is transferred by radiation in the furnace.

Q_2 that part which is transferred by contact of heated gases in the furnace.

Q_3 the part which is transferred by contact of heated gases in the flues.

Then $Q = Q_1 + Q_2 + Q$.

In this expression, the first member may be regarded as known, because it may be easily ascertained by experiment. Of the terms of the second member, Q_1 represents the quantity of heat transferred by radiation from the surface of the fuel.

According to the laws of Dulong and Petit, this quantity may be represented by

$$Q_1 = q \times G = C.\ a^{\theta}\ (a^{t} - 1). \times G.$$

in which q represents the quantity of heat transferred by radiation from one square foot of grate surface in a unit of time, G the grate surface in square feet, C a constant, $a = 1.00077$. θ represents the temperature of the absorbent body, or the water in the boiler (a constant which may be determined by observation), and t the difference between this temperature and the higher temperature of the incandescent fuel.

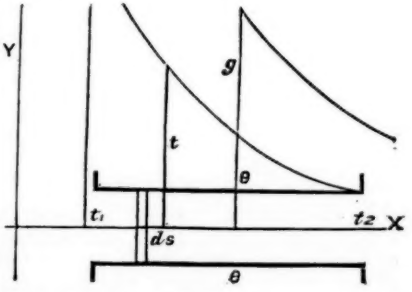
By the law of transfer of heat by contact of gases, given by Dulong and Petit, we shall have

$$Q_2 = F. \times C.' t_1^{\ 1.233}.$$

F representing in square feet the furnace surface, $C' t_1^{\ 1.233}$ the quantity of heat transferred by contact of the gases in the furnace in a unit of time; in which t represents the difference of temperature between the gases in the furnace, and the temperature, θ, of the water in the boiler; this difference being constant for the whole furnace surface. It is presumed that the law of Dulong and Petit for *the cooling of bodies by contact of a cooler gas is also the law of heating by a hot gas;* the side on which the excess of temperature exists being a matter of indifference.

For the transfer of heat by contact in the flues, the application of the law renders it necessary to take into account the diminution of temperature, from the initial temperature t_1 to the temperature t_2, of the gases, as they leave the flues and pass into the chimney.

Let the combined flue surfaces be represented by a single cylindrical surface in the form of a tube, as in the figure below, and



assume two co-ordinate axes, one in the axis of the tube and the other perpendicular to it; and let t_1 be the difference of temperature of the gases and the water outside of the tube, at the entrance, and t_2, the corresponding difference of temperature at the exit of the gases.

Let q represent the quantity of heat transferred in a unit of time (one hour) at any

point of the tube from one unit (square foot) of surface. When a boiler is at work the temperature of the gases at any point, or of the plates in contact with the gases, may be regarded as constant, and it will not, therefore, be necessary to regard the conductivity of the plates; this being necessary only when the surfaces of the plates undergo a change of temperature, as in getting up steam.

If the heating surface represented by the surface of the tube be divided into elementary portions by planes perpendicular to the axis, the element of the surface between two planes may be represented by $d\,s$, and the quantity of heat transferred by contact through the element will be represented by $q\,d\,s$.

If we represent by c the specific heat of the gases, by W the weight of gas which passes the element $d\,s$, in a unit of time (one hour), and by $d\,t$ the element of time; it is evident that the cooling of the gas in the time $d\,t$ will be $c\,\mathrm{W}\,d\,t$, expressed in units of heat, and this quantity must be equivalent to that received or absorbed by the water, represented above by $q\,d\,s$, a relation expressed by the equation:

$$q\,d\,s = c\,\mathrm{W}\,d\,t \text{ from which } d\,s = \frac{c\,\mathrm{W}\,d\,t}{q}.$$

Introducing now the law of Dulong and Petit, by substituting for q its equivalent $\mathrm{C}'\,t^{1.233}$, the expression becomes

$$d\,s = \frac{c\,\mathrm{W}\,d\,t}{\mathrm{C}'\,t^{1.233}}$$

or

$$\frac{d\,s}{c\,\mathrm{W}} = \frac{t^{-1.233}\,d\,t}{\mathrm{C}'}.$$

Integrating between the limits t_1 and t_2 we obtain

$$-\frac{s}{c\,\mathrm{W}} = \frac{t_1^{-.233} - t_2^{-.233}}{-.233\,\mathrm{C}}$$

from which the value of t_1 may be obtained.

$$t_1 = \left(\frac{c\,\mathrm{W}\,t_2^{.233}}{c\mathrm{W} - .233 \cdot \mathrm{C'S}.\,t_2^{.233}}\right)^{\frac{1}{.233}}.$$

In this expression S represents the whole heating surface of the boiler, or the surface of the tube, a known quantity; t_2 may be ascertained by observation with a common thermometer. But no accurate mode of ascertaining t_1 by observation has yet been found, and hence the necessity of this mode of determination.

In the second member of the equation the undermined quantities are W and C', the first representing the weight of gas which passes through the furnace in an hour, and the second the constant C' of the formula of Dulong and Petit.

If W be taken on the assumption, *generally acquiesced in*, that in ordinary boilers the quantity of air which passes through the furnace is just double the quantity necessary for perfect combustion, and we assume for C the value given by Mr. Hopkins for carbonic acid gas, the value of t_1 is completely determined; and to find the initial temperature of the gases, it will be only necessary to observe, with the aid of a common thermometer, the temperature of the gases at their exit from the tube or boiler. Having found t_1, the quantity of heat transferred by contact of the gases, in the flues, to the water, will be represented by

$$c\,\mathrm{W}\,(t_1 - t_2).$$

The value of Q then becomes

$$\mathrm{Q} = \mathrm{C}.\,a\theta.\,(a^t - 1)\,\mathrm{G} + \mathrm{F}.\,\mathrm{C}'.\,t_1^{\,1.233} + c\,\mathrm{W}\,t_1 - t_2),$$

in which all the terms become known, except the first term of the second member.

The value of the expression $\mathrm{G} \times \mathrm{C}.\,a\theta\,(a^t - 1)$ being thus determined, the separate influence of the radiant heat of the furnace becomes known, and the value of t, the difference of the temperature between the *fuel and the water*, may by the aid of Hopkins' value of C, be ascertained.

Resuming the expression $\frac{d\,s}{c\,\mathrm{W}} = \frac{t^{-1.233}\,dt}{\mathrm{C}'}$, if we suppose the tube to be extended indefinitely and the gases to be forced through the tube by some extraneous pressure, the difference between the temperature of the gas within the tube and the water would ultimately become zero.

Integrating the above expression between the limits t_1 and t_0 we should obtain an expression by which the relations of t and S. and of q and S. become known; t, the difference of temperature at any point, will be $t = \mathrm{C}''\,\frac{1}{\mathrm{S}^{4.3}}$ and $q = \mathrm{C}'''\,\frac{1}{\mathrm{S}^{5.3}}$, equations which indicate the form of curve of temperatures along the axis of the tube, and also the form of curve of emissions of heat along the axis. It is evident that these curves approach the axis rapidly. The constant C' and C'' involve both c W and the constants of the law of Dulong and Petit, and the curves may therefore be constructed by assuming these as before.

Unfortunately, however, it is not probable that either of these quantities can be assumed in the present state of knowledge of the action of chimneys, the combustion

of fuel, and the phenomena of transfer of heat. It is certain that the assumption of twice the quantity of air necessary for combustion is not a universal law. And in regard to the constants of the formulas of Dulong and Petit, it can hardly be said that they have been completely determined or interpreted. The quantity of heat transferred by contact of a gas depends on the mode or rate at which the gas is supplied to, or removed from, the surface to be heated or cooled. This is the principal element in the problem. It seems evident that, according to the present state of knowledge of the *conductivity* of gases, heat must be transferred with excessive slowness, unless currents are established in order to bring fresh particles of gas in contact with the surface to be heated or cooled each instant.

By making use of an apparatus like the steam boiler it may be possible to determine these constants, as well as the quantity c W, for different dimensions of chimneys or force of draft, thickness of bed of fuel, etc. It would be necessary to make experiments under such conditions that some of the quantities could be elminated, as, for instance, the initial temperature. If the same chimney be employed with the same kind of fuel, thickness of fuel on the grate, and under the same general conditions of barometer and thermometer, the initial temperatures must be the same, and, by properly varying the heating surface, different values of the final temperatures might be obtained and observed. The quantity of air used being measured, the law of change of temperature, or of transfer of heat, might then be ascertained for the flues and for the furnace separately.

If the laws of Dulong and Petit be true for high temperatures, it is apparent that the influence of the furnace at high temperatures must preponderate. Under any circumstances, it seems impossible to find a *scientific* solution of the important problem of efficiency of boilers in the generation and transfer of heat, until these questions are solved.

The laws of Dulong and Petit have not been verified for high temperatures. At very low temperatures the quantity of heat transferred by contact of a gas and by radiation, according to these laws, will be nearly identical, and the higher the temperature the greater becomes the difference in the effects.

Common observation shows that to heat or cool a body rapidly by contact of a gas, the gas must be supplied and removed rapidly. It seems improbable, therefore, that there can be any general expression for the quantity of heat transferred in this manner which does not involve this idea in some other way *than by the constants which have been adopted.*

The mode of determining the initial temperatures of the furnace and gaseous products of combustion generally employed, up to the present time, has been to assume, from the partial experiments of Péclet and others, that half the heat of combustion is usually imparted to the gases, while half passes off as radiant heat, and then to estimate the temperatures on the further assumption that a definite known amount of air passes through the furnace for each pound of coal burned. From the nature and phenomena of combustion it can hardly be supposed that any such law as that assumed by Péclet can be universally true. The temperature of the residue of solid combustible must depend on the special circumstances of combustion in each case, and especially on the law of radiation, at different temperatures.

If it were possible to observe accurately the temperatures of furnaces and flues, the solution of all these questions would be greatly simplified; and the discovery most needed to advance this branch of physical research is a thermometer for determining high temperatures. The only method available at present seems to be that of going back from a temperature which falls within the range of ordinary thermometers to the initial temperatures, by analysis. And the mode of investigation herein suggested is offered as one which apparently conforms to known or accepted laws, and does not require doubtful assumptions. Whether the laws of Dulong and Petit are true for all differences of temperature, and whether these laws may not be revised so as to involve directly the dynamic theory of heat, are questions which such investigation may help to solve.

The complete expression for the total heat of combustion of fuel in the boiler will be

$$\begin{aligned} \mathrm{E} &= \mathrm{Q} + \mathrm{E}_1, \\ &= \mathrm{Q}_1 + \mathrm{Q}_2 + \mathrm{Q}_3 + \mathrm{Q}_4 + \mathrm{Q}_5 \end{aligned}$$

in which Q_4 represents the heat in the gases after they leave the flues, represented by $c\mathrm{W}(t_2 - t_0)$, and Q_5 the losses from external radiation, incomplete combustion, etc., which can be only estimated.

BITUMEN, AND ITS PRACTICAL APPLICATIONS.

From "The Builder."

The application of bitumen interests so many of our readers at this moment, that we have thought it desirable to translate some observations on the subject published in the "Bulletin de la Societé d'Encouragement pour l'Industrie," August, 1872:—

Bitumen has been known from a very remote antiquity. In ancient days, at Babylon, and elsewhere in the East, it took a place amongst building materials; but the mortars and cements, first skilfully elaborated by the Greeks and Romans, have found greater favor in modern times. After having been abandoned for ages, the application of bitumen to purposes of construction was revived about the year 1840. Bituminous cements were then tried in France for covering footways and roofing vaults and arches. The success which attended these experiments attracted public notice, and cements of this description came speedily into vogue.

The rage for bitumen, and the bituminous compounds, all and sundry, which made their appearance about this time; the impetus thus given to the trade, and its varying fortunes and deserts, are within the personal recollections of many of us. Briefly, besides the cements formed of native asphalt from the mines of Seyssel, and of bitumen from Lobsann, there appeared a multitude of similar compounds, made with spurious bitumens obtained from the refuse of the gasworks, which were foisted upon the public as equal, or superior, to native asphalt. The failure of most of these substances bade fair to ruin the new industry; but time and perseverance have shown the utlity of certain of them, and we have now natural and artificial bituminous cements, each having a recognized place and uses in construction. The success which attended the employment of asphalt as a covering for pavements and footways generally, naturally suggested its application to streets and roadways, and many unsuccessful attempts were made in this direction. Not until twenty years later was the difficulty practically solved by the formation of the roadways of "compressed asphalt," which now covers some five thousand running métres of the Paris streets, and which our neighbors across the Channel began about the same time to use as a substitute in the streets of London for "macadam," of which they, like ourselves, had experienced the inconvenience.

Bitumen, which would appear to be the result of a subterraneous process of distillation of organic matter or of coal or lignite, is still involved in considerable obscurity as to its origin. Numerous theories have been broached to account for its formation, and impregnation with various matters found in combination with it. Moreover, chemically considered, it is a very complex substance, formed of various compounds of hydrogen and carbon. Just as fatty matters are made up of oleine and stearine, so bitumens consist of a highly carbonized solid substance, combined or amalgamated with certain essential oils of a more or less volatile character. When exposed to the air, these oils evaporate slowly, giving rise to the varying states—solid, viscous, and liquid—under which bitumen is found in nature. Originally, the terms bitumen, mineral-pitch, mineral-tar, asphalt, and the like, were applied rather vaguely to denote the degree of consistency of the material. At present, in accordance with the system of nomenclature proposed by M. Milo, in 1861, the term *bitumen* is applied to the bituminous principle in all compounds of this class, whilst *asphalt* is restricted to those compounds of bitumen with calcareous matter, which form the basis of the cements in use for paving purposes, and the substance of the "compressed asphalt" now employed on our carriage-ways.

Bitumen is widely distributed in nature. It is met with in various states:—1. Free and unmixed. 2. In a state of admixture with quartzose sand or earthy matters. 3. Impregnating schists. 4. In a state of combination, or of more or less intimate admixture with calcareous rocks, in which state it constitutes the substance we know under the name of asphalt.

Springs of pure bitumen have been known from a very high antiquity; but those which would seem to have been formerly very abundant are now much reduced, and their yield gets smaller year by year. Those of Judæa, which furnished the bitumen employed at Babylon, give scarcely any yield; that of Gabian, in Herault, which formerly gave 1,500 kilogrammes per annum (3,300

lbs.) is now almost exhausted; and the famous "pitch fountain" at Clermont is well nigh dried up. It would appear, however, that in China the supply is still abundant. Near the Cape Verdes, the bitumen at times overflows the surface of the tide; and in certain places in the Holy Land it rises to the surface of the water in a sort of scum, which is drifted to shore by the wind. In the island of Trinidad, on the bed of an ancient lake-basin now dried up, are found masses of bitumen solidified by the evaporation of their essential oil or by the addition of foreign substances. Bitumen in a pure, unalloyed state, as it here occurs, forms, as we have said, the basis of all bituminous cements.

At Seyssel, at Bastennes, in Auvergne, and in numerous localities in France, Spain, and Switzerland, may be found beds of sand impregnated with bitumen. These *molasses* are generally in the vicinity of deposits of asphalt, most frequently below them. The bitumen is extracted from the sand by long boiling in water, during which process it rises to the surface like a scum. Lastly, bitumen, in a vaporous as well as a fluid state, appears to have made its way, under conditions at present unknown, into the marls, schists, and jurassic-limestone beds of the lacustrine epoch, in which it exists in a state of admixture, perhaps even of combination.

Bituminous schists are extremely plentiful in the coal-basins of Autun (Saone-et-Loire), of Buxiere (Allier); and are also found in Provence, in Dauphigné, and doubtless in many other localities. Calcareous bitumen appears to be of rare occurrence as it also is of greater industrial utility. In France, we know at present but of four or five deposits susceptible of being advantageously worked. The oldest and best-known are at Seyssel, Seyssel-Volant, the Val de Travers, in Switzerland, and at Maestra, in Spain. Latterly some deposits have been opened in Haute-Savoie, and several beds near Alais, which, in the excellency of the yield, bid fair to rival that of Seyssel or of the Val de Travers. Some trials have also been made in Auvergne, in the neighborhood of Clermont, but the proportion of bituminous matter in the limestone is too variable and uncertain hitherto to admit of its being worked to profit.

Bituminous limestone, or asphalt properly so called, has the appearance of mortar. Its color is chocolate, of a shade depending upon the proportion of bitumen contained in it. When broken, it shows a fracture of a lighter color, such as a scratch with a knife leaves on the surface of chocolate in cake. The grain is fine, and a close inspection shows that each grain of limestone has a separate bituminous envelope; each grain is thus parted from its neighbors by a coating of varnish, which varnish binds the whole together firmly in mass. In hot weather this varnish becomes soft and sticky, and oftentimes the weight of a block in itself is sufficient to cause rupture. In winter, on the contrary, the bitumen is dry, and the mass presents a remarkable degree of hardness and impenetrability. When heated on an iron plate to a temperature of 170 deg. to 180 deg. Cent. (338 deg. to 356 deg. Fahr.), asphalt decrepitates and falls to powder.

The proportion of bitumen in asphalt ranges from 15 down to 7 or 8 per cent. Generally speaking, those from the Val de Travers and Haute-Savoie give an average of 12 per cent. Seyssel asphalt yields 8 to 10 per cent. only. In the works in the Department of Gard, which are in a series of superposed beds, the proportion varies considerably, but the percentage is uniform throughout each individual bed. The richest yield 15 to 20 per cent., and the poorest 7 to 8 per cent. But the proportion of bitumen even in the richest beds is not sufficient to cause them to soften in hot weather. When, after breaking the asphalt into 3 in. or 4 in. fragments, we heat it to a temperature of 130 deg. to 140 deg. Centigrade, it falls to powder, as we have before said; and if the temperature be raised still higher, the bitumen passes off in the form of a thick smoke. If, on the other hand, we cast the powdered asphalt into pure molten bitumen, it dissolves, so to speak, and as much as 90 per cent. may be added before the mass assumes a paste-like consistency. Upon this singular property is based the process of manufacture of bituminous cements.

Formerly, Bastennes, in the Landes, and Lobsann, in the Bas-Rhin, supplied a sufficiency of bitumen in a fluid, or, at any rate, in a viscous state, for this purpose; but now the springs appear to be nearly exhausted. Pure bitumen can only be obtained by boiling the *molasses*, or bituminous shales, for a lengthened period,—say, ten or twelve hours. This is the mode of procedure at Seyssel; but it is costly and incomplete, and

the bitumen thus procured always retains a certain proportion of sand. Even at Seyssel, where the shale is in close proximity to a rich deposit of asphalt, the process has been well-nigh abandoned; and there, as elsewhere, the native bitumen has been given up for dry bitumen from Trinidad, dissolved in mineral tar, obtained by a second distillation of certain bituminous shales found in considerable abundance in the Department of Air.

To 800 kilog. (1,760 lbs.) of Trinidad bitumen are added 250 kilog. (550 lbs.) of mineral tar, and the whole is boiled, stirring well the while, for the space of ten hours. In this way we get what is called "refined bitumen," which now takes the place of that from Bastennes and Lobsann.

To form the bituminous cements used for paving, etc., we throw into the molten bitumen aforesaid, by degrees and stirring well the while, the fragments of asphalt reduced to a powder, either by the action of heat or by mechanical pressure. The latter method is to be preferred, as it precludes the possibility of the bitumen getting burned. 100 kilog. (220 lbs.) of refined Trinidad bitumen will thus take up 1,400 kilog. (3,080 lbs.) of powdered asphalt. After six or seven hours' cooking, the compound assumes a paste-like consistency, and is then run off into moulds bearing the trademark of the manufacturer. In this way are obtained the blocks in which asphalt is offered for sale. Formerly it was the custom to melt these blocks on the spot, with the aid of a portable furnace, and the addition of six or seven parts by weight in the hundred of pure bitumen. After melting, 60 to 70 per cent. of fine gravel was stirred in, and the mixture laid on hot. But the smoke and the disagreable smell thus entailed were productive of serious inconvenience in the Paris streets, and latterly the cement has been amalgamated with the sand or gravel at the contractors' works, and brought to the required spot in covered conveyances, provided with small coke furnaces, for keeping the contents at the requisite temperature. The latter are stirred from time to time by means of an "agitator," worked with a rotary handle. The success which attended the use of bituminous facings for footways naturally led, as we have already observed, to a desire to apply the material to carriage-ways, equally either in the form of concrete of small stones embedded in some bituminous cement, or by flagstones, cemented together with asphalt. But, in each case, the alternations of temperature and humidity destroyed the setting, and the essays proved unsuccessful. Numerous other attempts proved equally abortive, and it was only after many long years of experiment that it was found practicable to form roadways of compressed asphalt, such as now covers over 40,000 sqnare metres of the Paris streets, and is rapidly coming into favor in England. It should be stated that, although the experiments at Paris were unsuccessful, at Seyssel and at the Val de Travers the roadways formed by the continuous droppings of fragments of asphalt have a smooth, homogeneous surface, very compact and very durable. This fact suggested the application of the material in its natural state, as in the roadways now laid with "compressed asphalt," as it is termed.

For this purpose the asphalt is reduced to a fine powder, and heated to a temperature of 130 deg. to 140 deg. Cent. (260 deg. to 280 deg. Fahr.) It is spread out in layers, of 2 in. in thickness, over a concrete flooring, and well compressed by ramming, until cool. It forms a compact mass, as homogeneous in its powers of resistance as the rock itself in its natural state. At first, the asphalt was pulverized, by breaking it into 4 in. to 6 in. fragments, which were placed on strongly heated iron plates. This method was only applicable to the richest asphalts, as that of the Val de Trawers, and the bitumen often got burned in the process. Nowadays it is pounded cold by a very ingenious mechanical arrangement, equally applicable to any sort of asphalt, so long as it contains 7 or 8 per cent. of bitumen. The powdered asphalt is placed within large horizontal drums of plate iron, revolving over portable furnaces, which, with the aid of a system of rails and turntables, can be run under them as required. When the powdered asphalt has acquired a temperature of 150 deg. Cent. (300 deg. Fahr.), the portable furnaces are withdrawn, and in their place covered trucks, with double sides, to retain the heat, are run in under the drums to receive their contents, and to wheel them off for immediate use. The loss of temperature in the trucks is small, and on arrival at its destination the powder is spread out and rolled with slightly-heated rollers into the requisite state of pulverization.

The success of the operation depends

much upon the state of the weather. In cold, and particularly in damp, weather, the powder cools too quickly; it then binds well at the surface only, and when the surface goes the road is destroyed.

Very many roads which have been made or repaired in unfavorable weather have lasted a very short time. Now, in Paris, operations of this description are no longer performed in winter,—all alterations and repairs are deferred until the summer, the stopping of holes and the like being done provisionally with boiling pitch, until the weather will admit of their execution in a proper manner.

Roads formed of "compressed asphalt" are cheaper in respect both of prime cost and of maintenance than ordinary macadamized roads. They produce less noise, less mud, and less dust. The resistance to traction upon them varies much according to circumstances. In winter it is less than over a flagged road; in summer-time, on the contrary, it is greater than on a paved road. Their greatest defect is that they become very slippery when covered with a thin coating of mud; they should therefore always be kept clean swept. Their greatest practical inconvenience is, as we said, that repairs can only be effected at particular seasons.

REPORTS OF ENGINEERS' SOCIETIES.

LONDON ASSOCIATION OF FOREMEN ENGINEERS.—At the last monthly meeting held on Saturday, September 7th, Mr. Joseph Newton, for whom much sympathy was expressed, was absent on account of the recent death of his only daughter. Mr. Gibbons was called to the chair, and Mr. Thorburn to the vice-chair. Mr. Moore and Mr. McKean were put into nomination for election at the next meeting. Mr. Nicholson presented a paper on "Continuous Expansion Engines," which he illustrated by several drawings and diagrams. He said that the only engine on the compound principle at present in the market, as a competitor to Woolf's, was the engine which he now described. The steam was worked in a different manner from any other engine; it was cut off at about half stroke on the small piston. When that has passed the cellular ports in the sides of the small cylinder the two pistons begin to share the steam between them, and both begin to expand the steam. When the small piston has finished its up or down stroke, the large piston continues to expand the steam until nearly the end of its stroke, which causes it, as its name denotes, to be a continuous expansion engine. Mr. Stewart, at Blackwall Ironworks, is now busy with the tenth boat on this principle. The engines of this boat, belonging to Egypt, are to be converted from ordinary condensing engines into continuous expansion engines. The paper was followed by a lively and interesting discussion, in which Messrs. Sax, Hedley, Galloway, Ives, Robson, Leith, and both chairmen, took part. The meeting adjourned at about 11 o clock to Saturday, October 5th, as usual at the City Terminus Hotel.

NEW YORK CHAPTER OF THE AMERICAN INSTITUTE OF ARCHITECTS.—At the sixth annual meeting—and first regular business meeting—of this Chapter for the current official year, 1872-3, held at these rooms last night, the following officers and Standing Committees were elected: President, James Renwick; Vice-President, R. G. Hatfield; Treasurer, Henry Fernbach; Secretary and Librarian, A. J. Bloor. Executive Committee—James Renwick, Chairman, Henry Fernbach, A. J. Bloor, R. G. Hatfield, Carl Pfeiffer, N Le Brun. Committee on Admissions—H. Hudson Holly, R. M. Upjohn, Wm. T. Hallett, Geo. B. Post, James Renwick, ex officio. Committee on Library and Publications—R. M. Hunt, C. C. Haight, Chas. D. Gambrill, A. J. Bloor, James Renwick, ex officio. Committee on Education—E. T. Littell, Alfred H. Thorp, James Renwick, ex officio. Committee on Examinations—R. G. Hatfield, Henry Dudley, John W. Ritch, A. J Bloor, James Renwick, ex officio. The Committee on Examinations are the appointees of the Chapter, under Act passed by the Legislature of the State of New York, April 20th, 1871, entitled an "Act to amend and reduce to one Act the several Acts relating to buildings in the City of New York.' Sections 37 and 42. The Library of the Chapter is open to all practitioners and students of architecture and the cognate arts.

THE SCIENTIFIC AND MECHANICAL SOCIETY, MANCHESTER.—At the last meeting of the above Society the subject announced for the discussion "On the Steam Jacket" was briefly introduced by Mr. Hildebrandt, who explained the object of the appliance. The question at issue was whether the unavoidable liquefaction of steam, due to condensation from radiation, conduction, and convection, and that due to work done, was to be allowed to take place in the cylinder itself, or whether it was more advantageous to employ a separate casing to supply heat to the steam inside the cylinder, and let the condensation take place in the casing, so that the propelling steam was uninfluenced by loss of heat from convection. Condensation would take place under all circumstances, even if we could construct the vessels in which the steam had to perform work of perfect non-conducting materials. So far from being able to do this, it was evident that the liquefaction due to radiation and conduction would be greater where a steam jacket was used, owing to a somewhat larger radiating surface of the jacket, and more than double the quantity of metal to be treated where the jacket was applied; but it was thought by many eminent philosophers and practical men that the evils arising from the influence of convection in the cylinder did more than balance those due to increased radiation and conduction. If there was an advantage, however, in point of economy, it was a doubtful one, notwithstanding that we saw nearly all the steam engines in open competition trials steam jacketed or with hot air jackets. Jackets always did, not to an inconsiderable extent, increase the first cost of an engine.

A very animated discussion followed, in which nearly all those present took part; one speaker advocated the jacket because it was a safeguard against breakage, resulting so often from accumulated condensed water in the cylinder. This argument was strongly opposed by all subsequent speakers, most of whom were adverse to the use of the appliance under consideration. Some of them stated that from experiments they had made they were forced to the conviction that no advantage could be gained with the steam jacket.

The result of the discussion was that all those present—with one exception—expressed themselves to the effect "That no advantage could be gained with the steam jacket, nor did they object to its use; but they were convinced that efficient protection against radiation and conduction of heat from the cylinder was the best and only means to attain true economy."

IRON AND STEEL NOTES.

CEMENT MIXTURE FOR STEEL.—Mr. Edward F. Houghton, of Philadelphia, proposes to use a combination of bone-carbon and hydrocarbon oils as a cement mixture for the manufacture of steel. The object of the invention is to convert iron into steel economically, and to utilize the waste bone accumulated in the process of manufacture of the article known as cosmoline. The bone carbon is impregnated with hydrocarbon oil.

The wrought iron is case-hardened by immersion in the described bone-carbon, heated to redness. The surface of the iron is of extreme hardness, and the metal is not blistered—a desirable feature in finished work.

PURE WROUGHT IRON.—It has hitherto been deemed impossible to make pure wrought iron; this has been done at the Bowling Ironworks, Bradford, from Bowling No. 2 Pig iron, by the Henderson process.

The analysis of the pig iron used is:—

Graphitic carbon	3.155
Combined do.	.581
Silicon	1.346
Sulphur	.060
Phosphorus	.635
Manganese	1.472
Iron	92.644
	100.203

The wrought iron from the above analysis:—

Carbon	.272 per cent.
Silicon	None
Sulphur	The barest trace.
Phosphorus	None
Manganese	None
Iron by direct determination.	99.500
	99.772

This is the purest iron ever made on a commercial scale of manufacture.—*Mechanics' Magazine.*

AN article in "Engineering" calls the attention of manufacturers of iron houses to the fact that such houses are almost unknown in Austria, where rents are enormously high and ordinary building materials are extremely dear. Among the novel features in the coming Vienna Exhibition, is a collection of examples of dwelling-houses, represented by models, drawings, and full-sized thoroughly furnished apartments. If good types of iron buildings were sent for exhibition and for use, the rents that could be collected from them would be remunerative, and a lucrative trade could perhaps be established.

RAILWAY NOTES.

ENGLISH RAILWAY DISASTERS.—It has been generally supposed that railway travelling in Great Britain is safer than in other countries. Official returns to Parliament, however, have rudely shattered this hypothesis. It appears that in the eleven years from 1861 to 1871 inclusive, there were killed and injured as follows:

	Killed.	Injured.
1861	284	883
1862	216	600
1863	284	470
1864	222	794
1865	221	1,132
1866	215	634
1867	209	795
1868	212	600
1869	321	1,252
1870	86	1,239
1871	404	1,261

Here is a total of persons killed in 1871, more than 100 in excess of the fatal accidents in 1870, besides a steady increase in the number of persons injured on railways from 1861 to 1871, with the exception of a single year, when the comparative small number of 600 persons received hurts. It should be remembered, however, that a largely greater number of persons travel now than did ten years ago—railways having extended very greatly within that period.

The abstract of returns gives something of an opportunity to compare the security of life on railways in England and Massachusetts, the latter being taken as comprising the oldest railway enterprises of the country. The total mileage of Great Britain, December, 1871, was about 14,000; of Massachusetts at the same period about 2,400. The total killed in that State in 1871 was 162—about 40 per cent. of the number killed in Great Britain. The accidents not fatal in Massachusetts were but 13 per cent. of those in the former country. This comparison, however, is not very valuable, since we are not informed how many passengers were carried on British railways. The sad disaster at Revere, in Massachusetts, is also taken into the account above stated. A similar catastrophe may not recur in years. The showing made shows, after all, that human life is about as safe aboard the cars as anywhere else.—*Chicago Railway Review.*

ENGINEERING STRUCTURES.

SAN FRANCISCO BRIDGE TUNNEL.—Bids for construction were opened on the 12th. The stipulations provide that the work shall be commenced immediately after signing contract, and shall be completed by May 1st next, or by the time

the bridge shall be ready. A preliminary excavation has been commenced on Seventh street to ascertain the depth of the sewer at that point. It is confidently expected that the work will go forward, and the stupendous structure be entirely completed by the time above indicated, if not before.

PEORIA BRIDGE.—Two spans of the Peoria and Springfield R. R. bridge at P. have been completed, and all the piers are finished. Work is being pushed forward energetically, and the entire structure will soon be ready for the first train.

TRIALS OF ROAD LOCOMOTIVES.—Two six-horse road locomotives belonging to the Telford Pavement Company were tried at South Orange, N. J., on the 1st inst. by Prof. R. H. Thurston, of the Stevens Institute of Technology, to ascertain their power in ordinary work.

The engines are by Aveling & Porter, and are alike, except that the wrought-iron driving-wheels, which have oblique projecting strips riveted on with snap-headed rivets to dig into the road and give adhesion, had been removed from one of them, and broad, smooth cast-iron wheels had been substituted, to serve as rollers. These cast-iron wheels added 6,700 lbs. to the weight, making the total weight of this engine 18,348 lbs. Each engine has one cylinder, 7¼ in. in diameter and 10 in. stroke, geared to make 17 turns to one turn of the driving-wheels, which are 66 in. in diameter. The boilers have each 130 ft. of heating surface. The wrought-iron driver-engine is new, and its boiler not yet clean, and it primed so much as to render it less efficient than that of its companion, which has been long at work, and did not prime.

Early in the day, we were informed, one of these engines drew 16 tons (wagons included) up a grade of 1 in 10. There were no slipping of the wheels in any of the trials, so we could not well judge as to the need of rough tires. The heaviest load drawn was by the smooth-tired engine, 56,000 lbs., up a grade of 250 ft. per mile, at 3.6 miles per hour, the pressure falling from 103 to 90 lbs. in going 1,400 ft. The train consisted of 10 wagons, loaded with broken stones. Three horses to a wagon are used at this grade. The engine, therefore, drew the load of 30 horses, at a much higher speed than horses can draw such loads.

The road has a newly-made broken-stone surface, on a Telford foundation. Having been rolled, the surface must be in first-rate order; but it was dirty to such a degree as to make it much more resistant than an English road that is swept. But this makes the test more practical for our use, for we shall not soon incur the cost of cleaning roads outside of cities.

The cost could not be determined in a short time, but some of the employees of the Company thought it as low as a fourth of the cost of horse-power.

The engines are handier than horses. One man does all the work on an engine. With a train made to turn in the track of the engine, one additional man can manage the train. Thus two men can do the work of ten men with horses.

The quantity of fuel used had not been ascertained when we came away. But all reports concur in showing that the fuel costs very much less than horse feed.

The work was all done easily, without the least stoppage or delay. We saw no trouble with horses, though many were passing, and the steam blast was very loud when going up the grade; but Prof. Thurston said that some horses had shied, but were easily led past the train. Generally horses do not take fright; and the few that do at first, soon become reconciled.

We saw nothing to excite a doubt of the general opinion of the Company's employees, that the engines are much more economical and convenient than horses.—*Railroad Gazette.*

IRON PILING ALONG THE DELAWARE SHORE.—Under an appropriation of Congress a new pier was commenced last fall opposite the lower end of the long breakwater, a mile above Henlopen light, Del. shore. Several hundred feet are already constructed, but it will probably be a year before its completion. The length is to be 1,800 ft., and it is for the anchorage of vessels and the termination of the Junction & Breakwater Railway. That location was made for the purpose of changing the currents, by which the entrance for ships at the shore end of the Breakwater is gradually breaking up. The pier is built upon a stone abutment to high-water mark, then upon solid iron piles 6 in. in diameter, with a screw and flanges like those of an auger, at the bottom end of each (and known as the "screw pile"). The pile is screwed into the earth 9 ft. by means of a capstan upon the shore and a 2-horse power machine. The piles are set about 2 ft. apart in sections of 3 alternately on either side of the pier, standing in a triangular position to each other. The last pile driven is in 52 ft. of water, 9 ft. in the bottom, and was subjected to 11,000 lbs. pressure without settling. The structure appears light, and the piling does not obstruct the currents, as they do in cumbrous wooden piers. The labor is much less, and a pier upon iron piles is subject to decay only in the superstructure, which is repaired at a trifling cost, without interruption to business. The first cost is greater, but from its superior advantages it must eventually supersede wooden piling. It would seem that they would withstand much more pressure than the ordinary pile, the bottom of which is as small, if not smaller than the pile itself, while the flanges of the iron pile present more than quadruple its end surface to support its pressure. The engineers express entire confidence in it, and believe the iron piling will rapidly supersede the old wooden piling.—*Iron Age.*

FRENCH INLAND NAVIGATION.—A report upon the internal navigation of France has recently been laid before the National Assembly by the Commission of Inquiry upon railway and other means of transport, prepared by M. Krantz, chief engineer in the service of the Seine Navigation. It explains fully the actual condition of the water communications, and points out means for their improvement. The total length of the canal system of France, according to M. Krantz, amounts to 3,270 miles. The cost of constructing this mileage amounted to £32,746,000, and a balance of £1,319,000 remains to be paid. Including the cost of *personnel* and interest, the average cost per mile of canal has been £11,530. The maintenance of the canals cost £91.5 per mile, or about £300,000 a year. The duties collected by the State give a net product of about £129,000. The average ton mileage

is 841,847,830, and the net cost of transport is .288 of a penny per mile.

To obtain the actual cost of carrying each ton of merchandise, the maintenance expenses must be added to the interest of capital invested, and the amount divided into the whole tonnage. These two sums, cost of maintenance and interest of capital, amount to $1,920,000 per annum, this being the lowest sum that any company holding all the French canals in perpetuity should demand as toll upon the tonnage carried.

In this case the toll would be .557 penny per mile per ton, and this, added to the cost of transport proper, would bring up the total cost to .845 penny per mile ton. But if it be assumed that the canal system has already repaid to the country the capital expended upon it, through the services it has rendered, especially before the time of the railways, and that consequently the interest upon that capital should not be considered, then the cost of transport would be reduced to .307 penny per mile per ton. Now the railways in France cannot, at present at least, come down to this price, and under these conditions the system of navigable water-way presents an admirable means of providing cheap transport.

The alterations necessary to bring the French canal system into a useful condition may be classed under the four following heads:

1. The completion of the canals in each district, and opening up the necessary communications between the various systems.
2. The improvement of the existing canals.
3. The required financial and administrative reforms.
4. The reorganization of the boat service.

The report of M. Krantz does not enter with great detail upon the present condition of the French canal system, leaving this to the commission, that shall make a special work of inquiring into, and reporting upon, what must be done constructively; but he deals especially with the administration and financial reforms required for the navigation. He argues against the suppression of duties levied upon the canals, which only represent about 40 per cent. of the sums which the State expends annually upon the water-ways; but he seeks to abolish the excessive taxes levied under the forms of navigation licenses, passes, and other semi-official semi-administrative formalities, which are a serious impediment to the traffic.

As to the organization of the boat service, it is argued that it should be entirely a work of private enterprise. M. Krantz concludes his report by calling for the assistance of those most interested in the matter, to advance the costs of improvement; for this work, in the present condition of the French Treasury, must be carried out without aid from the Government.—*Engineering.*

GUNBOAT SERVICE IN FRANCE.—The opinion gains ground in France, as well as elsewhere, that powerful gunboats will in future form one of the most important branches of the marine, and Admiral Pothnau is engaged in the organization of special corps of workmen, founders, fitters, and engineers trained in the building, fitting, and refitting of gunboats for river and other service, but especially the former, where in future the employ of such boats should, it is said, be general. The maritime prefects of Brest, Cherbourg, Rochefort, and Toulon, have received instructions to furnish all possible information on the subject, and this fact proves pretty clearly that, although stress is laid on gunboats for river service, the new organization is not to be confined to them alone.

THE Tensas and Mobile Bridge, on the Mobile and Montgomery Railroad, in Alabama, extends from Tensas station, on the Mobile and Montgomery road, to the city of Mobile, a distance of 15 miles, crossing both the Mobile and Tensas rivers, and including draws, for each of the navigable channels into which the rivers are divided. The bridge itself is constructed of wood, but its pillars or supports are iron cylinders, which rest on a solid surface of wooden piles, driven down evenly with the bottom of the stream and the mud of the intervening morasses. It has been three years in the course of construction, at a cost of about $1,500,000.

RIBAND POSTS AND COLUMNS.—Telegraph posts for columns, etc., manufactured in Manchester, are formed of spirals of iron—ribands, in fact—supported on a cast-iron base, and surmounted with a capital of the same material. A slender rod forms the axis of the column, or, as it really is, a trellis-work tube. Compared with cast-iron columns, these structures are little more than one-third either in weight or cost, while in appearance the gain is decidedly great. For conservatories or other horticultural purposes the trellis column should be very suitable. Such a pillar, 11 ft. high and 8 in. in diameter, is guaranteed to support a vertical pressure of one ton.

HIGH PUMPING.—At Triumph, Pa., water has to be lifted from the Alleghany River to the summit of Triumph Hill, a vertical height of 685 ft. The horizontal distance is two and three-quarter miles. The pressure per square inch in the water cylinders of the steam pumps is 700 lbs. Three pumps are used, each lifting 200,000 gallons every 24 hours. The steam pumps have a piston stroke of 18 in.; the diameters of the steam and water cylinders are respectively 20 in., and 6 in. The pressure above mentioned in the water cylinder closely approaches that ordinarily employed in the cylinders of hydraulic presses.

ORDNANCE AND NAVAL.

THE DEFEAT OF THE GUNS.—The result of the contest between the 25-ton gun of the Hotspur and the turret of the Glatton is almost an exact counterpart of that obtained by the trials which took place on Friday the 15th of June, 1866, when the armor of the Royal Sovereign was attacked by the 9 in. 12½ ton gun of the Bellerophon, and this trial again finds its counterpart in September, 1861, when Captain Powell conducted a lengthened experiment against the cupola gun shield of Captain Coles on board the Trusty. In each case the heaviest available artillery was brought to bear against the shield; in 1861 the 100-pounder Armstrong attacked the light cupola defence; in 1866 the 12¼ in. gun was resisted by the 5½ in. plates, and 14 in. of teak backing, which formed the protection of the turret of the Royal Sovereign, and in

the recent trial, the 25-ton gun, throwing the 600-pound shot, was repulsed by the 15 in. of armor backed by 14 in. of teak, which was opposed to it on board the Glatton.

Satisfactory as these results are in one respect, pointing as they do to the continual precedence which the science of defence takes over that of attack, it must nevertheless be borne in mind that such a partial and peaceful experiment as that of Friday last cannot be compared to the rough realities of war. So far as it went, however, the trial was all in favor of the turret, and while we may congratulate ourselves upon the power of resistance it exhibited, we cannot regard with satisfaction the performance of the gun. True, the Palliser shots stood well to their work, the first one penetrating through 14 in. of armor plate, and 4½ in. of wooden backing, and making a gap of 2 in. between the upper and lower 15 in. outside plates, while the second shot, glancing on the glacis plate, penetrated 13½ in. into the armor. But the most unsatisfactory part of the trial lay in the difficulty experienced in getting the shots to go where they were wanted. Everything was in favor of the guns, far more in their favor than could ever be the case in action; both vessels lay securely moored upon the motionless water of a harbor, and within 200 years of one another. Under these circumstances, there should have been no difficulty in precise firing. Yet the four trial shots, "wobbling' as is their wont, played around the bull s eyes of the canvas targets in uncertain fashion; whilst the fifth—the first directed against the turret—missed it altogether. So with the remaining two shots, both of which were 18 in. too low. Now this inaccuracy is to be traced to the same cause which has proved so destructive to our heavy guns—to the form of rifling and to the studs upon the projectile, which impart an erratic impulse to the shot while in the gun, at the expense of the propelling force, reducing the velocity and diminishing the striking power of the shot. This result was anticipated by many distinguished artillerists present at the trial, who were well aware that the French rifling gives "decidedly the lowest velocities," and imparts insufficient rotation to the shot.

But if the work performed by the gun was unsatisfactory, at least the result given by the turret and the gun carriages was all that could be desired, the former being, as in the case of the Royal Sovereign, entirely uninjured so far as its moving capacity was concerned, and the letter remaining uaffected by the shock of the two projectiles, as was shown immediately after the trial, by firing the guns mounted upon them.

One fact is worthy of notice, that the concussion of the shot against the turret broke away a number of rivet heads, which were scattered with considerable force, and which would probably have caused serious casualties had the guns of the Glatton been manned. A precisely similar effect was produced by the guns of the Bellerophon inside the Royal Sovereign's turrets. We should have thought that the few lessons taught by that costly trial would not have been forgotten, and that the same result would not have been repeated last week.

Altogether we cannot see that the contest of last week has taught us much. We knew before as much about the power of resistance possessed by the Glatton shield, we knew as much of the uncertainty of the guns, and of the reliability of the Palliser shot. The Royal Sovereign trial proved conclusively that the great mass of iron and timber which forms the turret could not become deranged by two blows even from a 600 lbs. shot, and we knew that the concussion from such projectiles would call into existence a shower of bolts and rivet heads, that might be fatal to all within the turret.

We would by no means argue against occasional trials of the untested powers of resistance possessed by any given ship, but we think that these trials might be better carried out than by a partial destruction of the strongest armor that she carries, and which has been well tested on the sands at Shoeburyness.—*Engineering.*

UNMECHANICAL RIFLING.—At the recent meet- of the British Association at Brighton a paper was read by Mr. W. Hope, V.P., "On the Error in the Flight of Heavy Projectiles, due to the Woolwich System of Rifling Ordnance." And in the discussion which followed, Mr. Charles Merrifield, F.R.S., the able Principal of the Royal School of Naval Architecture, desired to speak on the general question of the Woolwich rifling. He said there was a close analogy between a screw of uniform pitch, that was a screw between two turns of which the distance was always uniform, so that it could turn in a nut without jamming, and a straight bolt sliding in a well-planed grove, or an eight-wheeled engine running on a straight line of railway. Altering the pitch (or twist) of a screw was equivalent to bending the slide or making the engine go round a curve. The bolt would not run in a bent slide unless the bolt bent also, and in order to make a long engine go round a curve, engineers had adopted the device of the bogie carriage. Now a rifled shot could not have a bogie carriage, or even a joint. As a result, instead of the Woolwich shot having flanges exactly fitting the gun, it was made to take the rifling by means of two rings of soft brass studs. The projectiles had to be weakened along regular lines in order to receive these, and they gave lines of weakness resembling those purposely made to facilitate the breaking of postage stamps from one another. This weakness impaired the destructive effect of the shot. The only reasonable ground which he had ever heard assigned for adopting this increasing pitch was the idea that the powder acted upon the rear of the shot very suddenly, like a kick given to a door, and that, consequently, the shot was impeded, and the strain in the gun increased, if it had suddenly to take up a considerable amount of rotation. But there was really no such abrupt action, and there was less excuse for the statement now than formerly, in consequence of the introduction of a slowly-burning powder, which produces less shock at first, while it gave the same muzzle velocity. Alluding to Mr. Chadwick's remark that the Woolwich authorities were under the disadvantage of having inferior metal to that used by Sir Joseph Whitworth, he fully admitted this to be the case, but considered it to be an additional reason for avoiding a system of rifling which tried the gun so unnecessarily as the Woolwich system. While the ordinary and proper "life" of a large gun was reckoned at 1,200 or 1,300 rounds at least, the 12½ ton gun in the Plucky was not allowed to fire more than 400

shot, and had actually been changed twice, for the boat to fire less than 1,200 rounds, the guns first used being returned to Woolwich. He also called attention to the limit imposed by the system of rifling both on the size of the guns and on the length of the shot; for the increase of these could not be met by a corresponding increase in the pitch of the rifling or of the distance between the studs. Naval designers were very much hampered in their work by this restriction of the efficiency of the implement, which was really the foundation and mechanical unit of their design of ships of war. After briefly describing the advantages and defects of the Whitworth system, Mr. Merrifield went on to say that the consent of all mechanicians and engineers with whom he had ever conversed was absolutely unanimous in the condemnation of the Woolwich system of rifling, and that he had never heard any serious defence of it. He could not attribute personal motives to any one, but he could not conceive of any reason why the authorities persisted in the use of the Woolwich system, except sheer obstinacy and unwillingness to admit that they were in the wrong—qualities of great value in an officer intrusted with the defence of a fortress, but very bad qualities in officers charged with the superintendence of mechanical work.—*Engineering.*

BOOK NOTICES.

PROFESSIONAL PAPERS ON INDIAN ENGINEERING. Second Series. Edited by Captain A. M. LANG, R. E., Principal, Thomason C. E. College, Roorkee. No. IV. April, 1872. Roorkee: Thomason College Press.

Two of the chief papers in this publication are on irrigation in India—the one titled, "Is Irrigation necessary?" by Captain C. S. Thomason, R. E.; and the other, "A Report on Certain Experiments in Irrigation," by E. C. Parmer, C.E., Exec. Engineer. It also contains reports, etc., on bridge foundations on Punjaub State railway; a paper on the Toolsee Water Supply Project, by Rienzi G. Walton, C. E., acting executive municipal engineer, Bombay; and matter on the subject of the Delhi Iron Pillar, with a frontispiece.—"Papers on Subjects connected with the Duties of the Corps of Royal Engineers. New series, vol. xx. Printed by Jackson & Sons, Wolwich. 1872. Includes notes on earthworks, demolition of bridges, huts in war, rails and turn-tables, tunnels, etc.

ON COAL WITH REFERENCE TO ITS SCREENING, TRANSPORT, ETC. By FRED. CHAS. DANVERS, Assoc. Inst. C.E., Assoc. Soc. Tel. Eng., of the Public Works Department, India Office, and late member of the Council of the Society of Engineers, London. Printed by order of the Secretary of State for India in Council. London: W. H. Allen, 13 Waterloo Place. For sale by Van Nostrand.

The above work, which also bears upon its cover the briefer title of "Coal Economy," comes before the public at an opportune moment. Every one nowadays is interested in knowing what are the existing sources of waste, and in becoming informed as to the means by which they are to be avoided.

The recently-published report of the Royal Commission on coal supply has furnished an enormous amount of information as to its sources, the loss which takes place in working, and the waste which ensues during its consumption; but it leaves comparatively untouched the treatment to which the coal is subjected on its way from the pit to the consumer; and it is this branch of the subject on which the book before us more especially bears. Mr. Danvers, however, gives some space to the consideration of other matters connected with the great question of "coal economy."

The treatise was first commenced in the form of a report on the subject to the Indian Government. This report was approved and ordered to be printed by the Secretary of State for India in Council, for circulation in India; but the author justly considered that the work would possess some interest for the general public. In the first chapter of the work, after some data referring to the coal supply in India, the author explains the general scope of his investigations concerning the screening, transport, haulage, and storage of coal, as at present practised in this country. Mr. Danvers observes that he has been able to discover no published books or papers whatever bearing upon these subjects, and the information conveyed in his book, therefore, is the result of direct personal investigations made in the South Wales and Northumberland and Durham districts. The special characteristic of "Coal Economy" is that it treats of subjects on which all who are concerned in coal supply should be well informed; but respecting which it has appeared hitherto to be nobody's business to collect information for the public use.

Mr. Danvers does not treat of the underground working of collieries, but takes the coal in hand at the pit's mouth, and traces its course and treatment until it arrives at the consumer. His second chapter, which is headed "At the Colliery," commences with some remarks on the "altogether coal," and "separation" systems of working collieries (the small coal being, according to the former, raised to the surface, while, according to the latter, it is left in the pit), and he gives some interesting data derived from actual observation as to the proportion of coal of different sizes obtained in various cases. Then follow descriptions, illustrated by lithographs of the trams in use in different districts for carrying the coal, notes on the arrangements of the "heapstead" at the pit's mouth, and very complete accounts of the principal varieties of screens in use, and their accessories, lithographed plates of a number of screens accompanying the descriptions. Mr. Danvers adduces many facts showing the losses at present caused by over-screening, and these are worthy of special notice.

Chapter III. deals with the transport of coal by rail, and commences with some observations on the breakage which takes place during transit. Mr. Danvers does not think that the amount of disintegration which takes place in the wagons increases in proportion with the length of the journey, but that the breakage is influenced in an important degree by the amount of shunting to which the trains are subjected.

In his fourth chapter Mr. Danvers deals with the treatment of the coal on its arrival at the depot, and points out the deterioration to which coal is subjected by exposure to atmospheric influences. The various arrangements of depots are also described, and their advantages and disadvantages

pointed out, while an account is given of various forms of screens.

That important branch of the subject—the shipment of coal—is considered in the fifth chapter, which contains illustrated accounts of the arrangements in use on the Tyne, and at Swansea, Cardiff, and Penarth, as well as particulars of the arrangements for discharging coal into canal barges employed in connection with some of our railways.

Next Mr. Danvers treats of the utilization of small coal, and his sixth chapter, is especially valuable, as it affords in a concise form a general summary of the plans which have been brought into use for turning small coal to good account.

The author s accounts of the various appliances and machinery which he describes are clearly written, and contain an amount of thoroughly detailed information which renders them especially valuable.—*Engineering.*

SPECIFICATIONS FOR PRACTICAL ARCHITECTURE. BY FREDERICK ROGERS. London: R. A. Sprigg, Atchley & Co. For sale by Van Nostrand.

This volume has been prepared on the basis of Bartholomew's work, which in its day rendered good service to the profession. It is devoted mainly to specifications for dwelling-houses of different classes, colleges, mansions, villas, and rectories, with a few for churches, schools, farm-buildings, and a workhouse. Altogether there are twenty-seven forms of specification. Every architect has, of course, a type of his own to which he is more or less partial, but the young practitioner especially may find much in the volume which is suggestive. For our own part we have a preference for specifications which may not be "models,' but have actually been employed, which have no blank spaces in them, but bear the names of the architects and builders; but possibly these would not be capable of as extensive use as those in the present volume. We think Mr. Rogers might have been a little more precise in some things, such as in cast-iron columns, for in no case does he mention the thickness of the shaft—in specifying tests; and we do not think there is any mention of wrought-iron girders in the volume. These things, however, can easily be amended in another edition. —*Architect.*

ILLUSTRATED CATALOGUE OF LOCOMOTIVES MADE BY THE BALDWIN LOCOMOTIVE WORKS.—Privately printed by J. B. Lippincott & Co., Philadelphia. 1872.

It has become so much a matter of course to step on a train in one city, and to be whirled away over the continent at a rate of forty miles an hour, and to be landed at any station at the exact moment given by the imperious time-table, that the traveller remembers with feelings of wonder, if he remembers at all, that the Rocket locomotive engine of George Stephenson is but 43 years old, and that the celebrated Rainhill contest, from which time the problem of rapid land travel was solved, took place in 1829.

The "Lives of George and Robert Stephenson," by Mr. Samuel Smiles, is an excellent history of the early progress in solving the problem, and of its later development in England, and the book owes its interest to the share which the general public feels in all connected with such improvements.

To the "Illustrated Catalogue" is prefixed a brief history, by an able hand, of American efforts in the same direction and it is on this account well worthy of notice. The Baldwin Works are now the largest in the world, and are exporting engines to South America and to Europe, and a view of their rise will be found to be a view of the rise of the present system of rapid locomotion, seen from its mechanical side.

In its forty-five pages is given a sketch of the changes in the locomotive engine from the early engines of the "Planet" class through many and various stages to the present fast passenger engine with 6 ft. drivers, capable of running sixty miles an hour, and to the modern freight engine which will haul a load on a level, of 2,000 gross tons, and which has eight drivers and weighs 96,000 lbs.

The first locomotive of the Works was the "Ironsides," and the faith of the Company by which it was owned (the Germantown and Norristown R. R. Co.) in its performance may be judged of by the following advertisement of its trips:

"NOTICE: The locomotive engine (built by M. W. Baldwin of this city) will depart daily when the weather is fair, with a train of passenger cars. On rainy days horses will be attached."

Succeding this engine came others whose history gives us a correct idea of the many problems to be solved, which to day and to us seem to have always been known: how to burn the various kinds of fuel, how to gain the proper amount of adhesion for traction, how to arrange the cut-off, the tubing of the boilers—these and a hundred more questions the practical skill of the early railway men of the United States gradually answered.

How recently this has been done in some cases may be seen in the fact that steel tires were first used in 1863, and that steel fire-boxes were not used till 1862, when the Pennsylvania R. R. had already 230 completed engines.

As a contribution to the history of Railroad Engineering in America this little essay is particularly valuable, and it is done in a very excellent manner. We should hardly expect witticisms in a descriptive catalogue, but we find that of one class of engines "all were short-lived, and died young, of insufficient adhesion."

The typographical execution of the work is of the very best, and it is illustrated by photographs of the completed engines. These features, with its other excellences, render it a valuable book, and an interesting contribution to an interesting History.

HEALTHY HOUSES: A HAND-BOOK OF THE HISTORY, DEFECTS, AND REMEDIES OF DRAINAGE, VENTILATION, AND WARMING. With upward of three hundred illustrations. By WILLIAM EASSIE, C. E. For sale by Van Nostrand.

This is an excellent little manual on sanitary science, intended, as the author observes, to be a record of facts—of acquired experiences and published inventions in relation to house-construction. It is both scientific and practical, the science being universal, and the practice English. But from a hygienic point of view, the subject of house-construction is much the same in given latitudes. Human life and its conditions being everywhere similar, wherever the largest number are "to be fed, housed, educated, amused, enriched, and all in the smallest possible space," which is Mr. Eassie's ideal of a

dwelling, the same questions must constantly arise, the same dangers are to be avoided, and the same advantages secured. The author has compressed an enormous amount of valuable information on the subject of sanitary construction within very narrow limits, and his book is written in an unusually compressed and pithy style. He gives descriptions of the best contrivances in use for attaining salubrity in all parts of the dwelling, and furnishes the reader with exact estimates of their cost. His book, indeed, is a condensed report upon the present state of art and science in England as applied to the utilities of household arrangement and construction.—*Popular Science Monthly.*

HAND-BOOK OF CHEMICAL TECHNOLOGY. By RUDOLF WAGNER, PH. D., translated by WM. CROOKES, F. R. S. New York. For sale by D. Van Nostrand.

The present edition of this exceedingly valuable work is translated from the eighth and last German edition. It is a complete cyclopædia of chemical processes. The contents of the work appear under eight divisions, and are in order as follows: 1st. Chemical Metallurgy, alloys and preparations made and obtained from metals. 2d. Crude materials and products of chemical industry. 3d. Technology of glass, ceramic ware, gypsum, lime and mortar. 4th. Vegetable fibres and their technical application. 5th. Animal substances and their industrial application. 6th. Dyeing and calico printing. 7th. The materials and apparatus for producing artificial light. 8th. Fuel and heating apparatus. The wood-cut illustrations, some 340 in number, abundantly illustrate the processes described in the text.

MISCELLANEOUS.

LIME A PRESERVER OF WOOD.—Lime is likely to be used largely as a preserver of wood. It has lately been discovered that vessels which carry lime last much longer than others. For a block pavement it is said an application of lime can be successfully made. In frame-houses, the space between the lath and siding could be filled compactly with lime, and the usual decay prevented at no very large expense. In regard to lime in connection with ship timber, the experience of an old ship-builder on the coast of Maine, published in the "Mechanics' Magazine," is of interest.

He had been in the habit of filling up the spaces between the timbers with hard stone lime, and ramming it in, calculating that slight leaks would cause the lime to expand and fill the crevices. Long observations had led him to consider lime a good preservative. A coasting schooner, built of Maine timber, unseasoned, and loaded with lime, had gone ashore and bilged. Being raised and repaired, the schooner remained sound for thirty years, with exception of the wood that had been used in making the repairs. It had been noticed, also, that the vessels carrying cargoes of lime generally lasted longer than others. But the most striking case was that of a platform of pine planks, used to mix mortar on, and that had been employed by father, son, and grandson, and, being no longer needed, was suffered to remain on the ground and became overgrown with grass and weeds. After a period of sixty years, having occasion to use the ground, the planks were removed, and found to be as firm and hard as when first laid down.

A NEW LIFE PRESERVER.—A correspondent, Mr. S. H. Starr, writes as follows: "I suggest the following as an improvement: A rubber garment like a pair of trousers, boots and all in one, lined with woollen stuff, reaching from the soles of the feet to the armpits, into which the person could thrust himself or herself, and then secure the garment in place by straps passing over the shoulders. Inside or outside of the garment under the arms, reaching down not much below the chest and forming a part of the garment, should be the buoying device, say an air-chamber surrounding the garment, or better, a chamber filled with cork chips; for when so filled an accidental leak will not destroy its buoyant qualities. Such a garment would securely buoy the body, and at the same time protect it from wet and cold."

ECHOES IN PUBLIC HALLS.—Architects and engineers are greatly puzzled many times to prevent echoes and annoying resonances in large high halls, and so too in depots. The latter buildings must almost necessarily be built so high between the joints, that almost the least noise in them, unless when pretty fully occupied by cars, etc., becomes a painful nuisance to the ear. The Bloomington "Pantagraph" alludes to just such a difficulty in the new Court House there, and its effectual remedy. A gentleman, Mr. W. S. Carlock, suggested that the stretching of small wires at a proper height and at suitable distances, would be of great benefit. This was tried, and the effect proves to be a vast improvement. From having been almost impossible to hear a speaker, there was no difficulty experienced in hearing an address to a jury delivered in easy conversational tones of voice. In any part of the room, from the remote corners to the centre, it was about the same. The theory is that the wires so small as to be hardly visible) break the sound waves and prevent the reverberation, hitherto the chief obstacle and annoyance. Three or four wires only, crossing the room, were found sufficient to effect this wonderful change. The subject is well worthy of the careful attention of engineers in putting up new depots. If practicable, the cure is certainly a cheap one.—*Am. Railway Times.*

TO CUT AND BORE INDIA-RUBBER STOPPERS.—In a letter to the "Chemical News,' Mr. W. F. Donking says:—"Dip the knife, or cork-borer, in a solution of caustic potash or soda. The strength is of very little consequence, but it should not be weaker than the ordinary re-agent solution. Alcohol is generally recommended, and it works well until it evaporates, which is generally long before the cork is cut or bored through, and more has to be applied; water acts just as well as alcohol, and lasts longer. When, however, a tolerably sharp knife is moistened with soda-lye, it goes through india-rubber quite as easily as common cork; and the same may be said of a cork-borer, of whatever size. I have frequently bored inch holes in large caoutchouc stoppers, perfectly smooth and cylindrical, by this method. In order to finish the hole without the usual contraction of its diameter, the stopper should be held firmly against a flat surface of common cork till the borer passes into the latter.